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DEMONSTRATION, MONITORING AND EVALUATION OF PRACTICAL VENTILATION SYSTEMS FOR NEW ALBERTA HOUSES

Alberta
MUNICIPAL AFFAIRS
Innovative Housing Grants Program

[redacted]

DEMONSTRATION, MONITORING AND EVALUATION OF PRACTICAL VENTILATION SYSTEMS FOR NEW ALBERTA HOUSES

December, 1989

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Edmonton Home Builders' Association

The views and conclusions expressed and the recommendations made in this report are entirely those of the authors and should not be construed as expressing the opinions of Alberta Municipal Affairs.

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FOREWORD

The project documented in this report received funding under the Innovative Housing Grants Program of Alberta Municipal Affairs. The Innovative Housing Grants Program is intended to encourage and assist housing research and development which will reduce housing costs, improve the quality and performance of dwelling units and subdivisions, or increase the long term viability and competitiveness of Alberta's housing industry.

The Program offers assistance to builders, developers, consulting firms, professionals, industry groups, building products manufacturers, municipal governments, educational institutions, non-profit groups and individuals. At this time, priority areas for investigation include building design, construction technology, energy conservation, site and subdivision design, site servicing technology, residential building product development or improvement and information technology.

As the type of project and level of resources vary from applicant to applicant, the resulting documents are also varied. Comments and suggestions on this report are welcome. Please send comments or requests for further information to:

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EXECUTIVE SUMMARY

INTRODUCTION

The ventilation and combustion air supply issue has been growing in importance over the past few years, principally because new housing has become increasingly tighter (better windows and doors, better air sealing techniques). In the 1985 edition of the National Building Code, the need for ventilation was recognized by requiring a capability of 0.5 ACH (air changes per hour). As well, combustion appliances were required to be supplied with their own combustion, dilution, and make-up air. This project addressed the need to develop and evaluate practical, verifiable and cost-effective ways to satisfy these new requirements.

OBJECTIVES

The main objectives of this project were to develop and field trial practical combustion air supply and ventilation systems suitable for use in typical new housing in Alberta; and to identify those that were most appropriate/promising on the basis of the following attributes:

- cost-effective in terms of equipment; installation and operation;
- understandable by the industry;
- within the capabilities of local building practice;
- achievable using hardware which is widely available; and
- reliable over time and operable by typical homeowners.

APPROACH

Following a review and analysis of various code requirements, eight potential methods of providing combustion air and ventilation air were developed and submitted to a project review committee consisting of a heating and ventilation design specialist, home builders, residential heating contractors, and building code officials. The potential methods proposed were an economizer system, a sealed furnace room, a blower assisted air supply, an induced draft fan, the Alberta Building Standards "Standata" system multiple air intakes and dampers, uncoupled appliances, and a heat recovery ventilator system.

The economizer, the sealed furnace room, the induced draft fan, and the Standata system were selected for demonstration and analysis on the basis of their predicted performance and estimated costs. These systems were installed and tested in four nearly identical split level houses in the Edmonton area. Subsequently, computerized data acquisition systems were installed to collect operating and performance data on three of the four demonstration systems. The collected data was analysed, and further special tests were carried out to evaluate resistance to backdrafting.

FINDINGS

1. General Performance Characteristics

Applicable codes now require that residential ventilation systems be capable of providing 0.5 air changes per hour. This may be done using kitchen and washroom exhaust fans and a remote fresh air intake, but such a system must not adversely affect appliances such as furnaces. However, the codes now in force do not identify acceptable pressure differentials or sizing guidelines for the fresh air supply.

During tests to verify that these systems performed as designed, the pressure difference between indoor and outside, and airflow readings for outdoor air, combustion air and exhaust air were recorded. The readings indicated that all mechanical systems were capable of exceeding the required 0.5 air change per hour ventilation rate. None of the houses exhibited dangerous depressurization. This was partially a result of relatively leaky building envelopes. In general, none of the washroom exhaust fans exhausted air at their nominal rated capacity. This was probably due to the pressure drop associated with the duct work connected to these fans. The kitchen range hoods all exhausted more than their rated nominal capacity. The performance of all exhaust fans would be reduced considerably if the building envelopes were tighter.

2. Performance of Individual Approaches

The following four systems were not tested for the reasons indicated:

i) The blower assisted ventilation and combustion air lacked a separate combustion air supply, which was felt to be necessary for safety in case of backdrafting, and required an interlock with the gas valve which could prove unreliable;

ii) Multiple intakes and dampers were considered too expensive and complicated;

ii) Uncoupled appliances had been tested and proven by previous researchers; and

iv) Heat recovery ventilators were considered to be too costly.

The other four systems were installed and tested, with results as follows:

i) The economizer system was effective in maintaining safe indoor pressure differentials but is too expensive for standard housing.

ii) The sealed furnace room, as installed, did not work. If a properly sealed furnace room were constructed, there is no guarantee that it would always function, as the door to the room could inadvertently be left open.

iii) The review committee concluded that the existing Standata requirements represent the most acceptable solution to the problem of satisfying the ventilation and combustion air requirements of the Alberta Building Code in typical production housing. This solution is understandable, reasonably reliable and not costly. However, caution must be exercised when sizing the fresh air duct. For buildings with tight envelopes, it is probably not suitable, since the fresh air duct would have to be so large that excessive ventilation flows would occur under certain conditions. For houses with tighter envelopes, the use of a draft inducer (subject to Gas Protection Branch approval), or induced draft appliances is recommended. The draft inducer was found to be capable of reversing established backdrafting at a negative pressure of 15 Pa.

iv) The computerized monitoring results confirmed that the Standata-based system was more than adequate as a ventilation and combustion air system in the relatively leaky houses tested. However, it did result in an undesirable continuous flow of cold outside air into the basement through the combustion air duct. A later revision of the STANDATA bulletin suggests a solution to this problem.

v) Low measured formaldehyde levels indicated that pollutant sources were being controlled while the low measured humidity levels indicated that these houses were actually being over-ventilated.

1.0 INTRODUCTION

The ventilation and combustion air supply issue has been growing in importance over the past few years, principally because new housing has become increasingly tighter (better windows and doors, better air sealing techniques). As well, there is a higher awareness among the industry and consumers about indoor air pollutants and the related adverse health effects.

In the 1985 edition of the National Building Code, the need for ventilation was recognized by requiring a capability of 0.5 ACH (air changes per hour). As well, combustion appliances were required to be supplied with their own combustion, dilution, and make-up air. However, the Code was silent on ways to achieve adequate air supply and ventilation rates. It has therefore been difficult for code authorities to enforce the requirement, or for builders to demonstrate compliance.

While much work is now underway in this area by housing authorities, building scientists and codes and standards agencies (like C.S.A.), Alberta Building Standards felt the need to take some action. Accordingly, Building Standards promulgated new combustion air requirements in STANDATA 85-DI-017R, which have been amplified by the City of Edmonton to include a related requirement for a balanced mechanical ventilation system. This report documents two projects which were carried out sequentially to address the need to develop and evaluate practical, verifiable and cost-effective ways to satisfy these new requirements.

The main objectives of the first of these projects were to develop and field trial practical combustion air supply and ventilation systems suitable for use in typical new housing in Alberta; and to identify those that were most appropriate/promising on the basis of the following attributes:

- cost-effective in terms of equipment installation and operation;
- understandable by the industry;
- within the capabilities of local building practice;
- achievable using hardware which is widely available; and
- reliable over time and operable by typical homeowners.

The scope of this first project included a review of ventilation and combustion air supply strategies for typical new housing built in Alberta, as well as the related building science issues. The focus was on developing and demonstrating alternative ventilation and combustion air systems which are cost-effective, within the technical capacity of the industry, reliable over time and operable by typical homeowners.

This study included a review of recent literature pertaining to ventilation and combustion air for housing. Engineering analyses identified the quantities of air required for combustion and ventilation. Building code requirements were reviewed. Potential methods considered for demonstrating the findings of the demonstration of the four selected systems are outlined in the report.

The objective of the second project covered in this report was to determine the reliability, workability, cost of operation and resistance to furnace backdrafting of three of the systems developed and installed under the first project. Systems were chosen for monitoring and testing on the basis of their merit and the relative lack of experience and data on each of them.

The scope of this second project included the computerized sensing and analysis of three ventilation and combustion air systems installed in two test houses. The three systems investigated were:

1. the bucket combustion air, ventilation to return air duct (as per STANDATA 85-DI-017R);

2. the above STANDATA system with the addition of a draft inducer fan in the common flue pipe serving the gas fired furnace and water heater; and

3. the economizer (mixing tee) system with a separate combustion air duct.

2.0 FINDINGS OF THE LITERATURE REVIEW

2.1 Introduction

Combustion venting failure can take the form of spillage, or in a more severe form, backdrafting. As defined in the CMHC report summarized in Appendix A.4,

Spillage is

> "The flow of combustion products out of the dilution device of a combustion appliance or out of leaks in its venting system into the room where the combustion appliance is located. This is caused by a condition where there is insufficient flow in the venting system to remove all of the combustion products emanating from the appliance."

Backdrafting is

> "A condition where all of the flow in a flue is downward and all of the combustion products from connected appliances, if operating, flow out their dilution devices along with the backdrafting air. Backdrafting can initially be caused by house depressurization or by downdrafting winds, but can sustain itself without either of the above, once started."

Several publications related to residential combustion venting failure were reviewed. Summaries of these publications are contained in Appendix A. The following is a discussion of the literature reviewed.

2.2 Residential Combustion Venting Failure

The various research projects undertaken to study residential combustion venting failure draw differing conclusions. A University of Toronto study states that "it is highly improbable that the maximum depressurizations found in houses by operating all the fans and the fireplaces at the same time will cause the chimney to vent improperly even in conditions under which venting failure would be most likely to occur (cool temperatures, low wind, cold chimney, large number of exhaust fans, weak venting furnace/chimney combination, relatively tight house)." (see Appendix A.1)

A CMHC study states that "some chimneys produce such low draft that even small depressurizations of the house can produce prolonged spillage and/or backdrafting. The combination of a weak chimney with a retrofit air tightened building envelope is now thought to be an important cause of the relatively high incidence of venting problems in pre-1945 housing stock found in the survey". The CMHC study also found that 17% of the houses surveyed on the prairies (Winnipeg) experienced "prolonged and unusual amounts of combustion gas spillage". This was attributed to "the colder climate and correspondingly tighter housing stock as well as the widespread use of stucco exterior cladding" (See Appendix A.4). Winnipeg was the only prairie location surveyed, but these conclusions appear to be applicable to Alberta housing as well, since typical houses in Alberta are only slightly less airtight than those in Manitoba. This is a strong indication that venting problems can be expected in new airtight housing in Alberta.

Both studies state different conclusions when worst case situations are studied (ie. weak draft chimneys, tight houses). Due to the opposing views on the incidence of improper venting stated by the above two sources, the question arises as to what constitutes improper venting. Does improper venting mean that spillage through draft diverters for any length of time, however minimal, is dangerous? Is dangerous carbon monoxide production an instantaneous result of downdrafting? The following may offer some answers to these questions.

Another University of Toronto study (see Appendix A.3) performed what was called a "Sealed Chimney Test" in which they artificially induced vent failure. The following conclusions were drawn:

.1 "More than a vent failure is needed to cause gas equipment to produce CO."
.2 Because downdraft in itself does not necessarily lead to CO production, another factor such as faulty equipment or reingestion by the burner of undiluted combustion products must be present.
.3 Associated with a depressurization induced venting failure there exists a continuous exhausting of inside air along with a continuous infiltration of outside air through the house walls and also down the chimney which will act to dilute the combustion products.

In summary, our review of currently available literature indicates considerable uncertainty concerning the incidence of downdrafting and the hazards associated with it.

3.0 COMBUSTION AND VENTILATION AIR REQUIREMENTS

3.1 Introduction

The following section outlines the air required for combustion and for ventilation. Detailed calculations are contained in Appendix B.

3.2 Stoichiometric Requirements

In stoichiometric combustion of a hydrocarbon fuel, fuel is reacted with the exact amount of oxygen required to oxidize all carbon, hydrogen, and sulphur in the fuel. Approximately 9.41 cubic meters of air is required for stoichiometric combustion of 1.0 cubic metre of Edmonton area natural gas. (See Appendix B).

3.3 Dilution Air Requirements

In addition to combustion air, atmospheric gas fired appliances require an approximately equal volume of excess air to ensure complete combustion of the gas and for mixing with the flue gases to reduce flue gas temperature and to ensure proper flow up the chimney.

Since 9.41 cubic metres of air is required for stoichiometric combustion of 1.0 cubic metre of Edmonton area natural gas then approximately 9.41 cubic metres of dilution air is needed.

3.4 Total Combustion/Dilution Air Requirements

Total air required for combustion and dilution is then 9.41 + 9.41 = 18.82 cubic metres of air per cubic metre of natural gas. From the heating value of natural gas calculated in Appendix B, the total air required can also be determined as a function of heat input, which is the usual method of rating gas fired appliances. Total air required for combustion and dilution is then 0.48 L/s per kW of natural gas input.

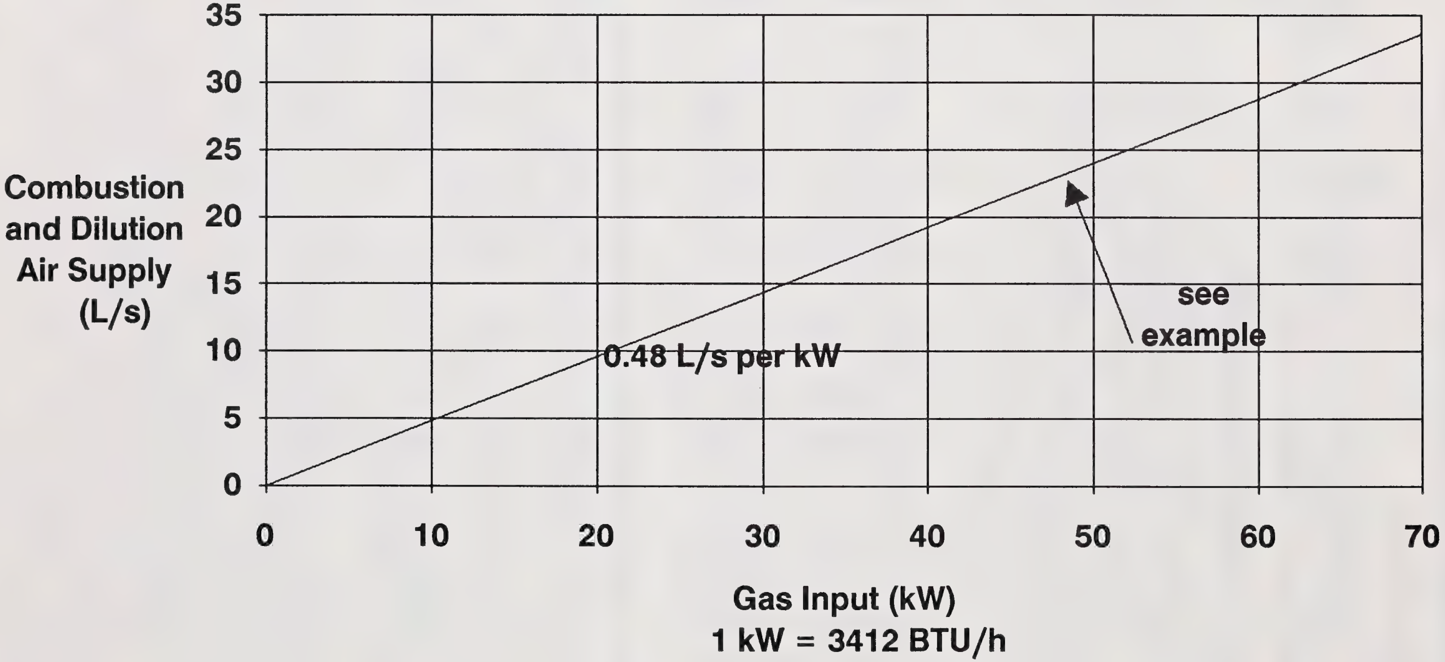
Figure 3.1 is then the basis for the determination of the flow rate (L/s) combustion and dilution air supply needed for furnaces and hot water heaters.

For example, a typical Alberta home would have the following gas-fired appliances:

furnace - 34 kW input (116000 BTU/h)
domestic hot water heater - 14 kW input (48000 BTU/h)

From Figure 3.1 using 24 + 14 = 48 kW total gas input (164000 BTU/h), 23 L/s total combustion and dilution air supply is needed.

FIGURE 3.1 GAS INPUT vs SUPPLY



3.5 Ventilation Requirements

The capability to provide one half an air change per hour (ACH) is required by the 1985 Alberta Building Code, Section 9.33.3.1 (see Appendix C).

To meet this requirement, 94 L/s must be supplied for a typical 139 square metre home. The cost of heating this air, assuming constant ventilation, is approximately $260 per year (See calculations in Appendix B).

This value is given to show an upper limit, or worst case, for ventilating at 1/2 ACH. It is unlikely that the ventilation system would be run continuously, especially during cold weather, so costs would be substantially lower for most homes.

4.0 ANALYSIS OF CODE REQUIREMENTS

4.1 Introduction

The following section discusses various regulations governing ventilation and combustion air supply for housing.

4.2 Alberta Building Code, 1985

The 1985 Alberta Building Code Article 9.33.3.1 (see Appendix C) requires that every dwelling "... shall have a mechanical ventilation system capable of providing at least one half an air change per hour...".

Article A-9.33.3.1 (see Appendix C) then goes on to state that "The requirement may be satisfied by means of exhaust fans located in kitchen or bathroom areas where a fresh air inlet is provided at a location remote from the exhaust outlet."

Article 6.2.3.12.(7) of the 1985 Alberta Building Code (see Appendix C) states that "During winter operation, make-up air that is introduced into a building shall be preheated."

The 1985 Alberta Building Code has adopted the above requirement for one half ACH from the 1985 National Building Code. Its intent is to ensure the supply of proper amounts of outdoor ventilation air to new airtight housing. Much research has been done on indoor air pollution and its effects on the long-term health of the occupants of new airtight housing (see Appendix A.5) and the above requirements follow from this research.

The required outdoor air need not be supplied on a continuous basis. The ventilation system must only be "capable of providing at least one half an air change per hour." It can be supplied as set out in Article A-9.33.3.1 but it must be preheated as per Article 6.2.3.12.(7).

The 1985 Alberta Building Code Article 6.2.3.12.(1) also states that "A sufficient quantity of make-up air shall be provided for a ventilation system that exhausts air to the outdoors so as not to adversely affect appliances in the building or the exhaust system." One of the intents of this article is to prevent the back drafting of the chimneys of combustion appliances. The logic behind this requirement is clear. If a mechanical ventilation system is exhausting more than it is intaking then the resulting depressurization in the house can cause backdrafting of chimneys. The question is how much negative pressure in the house is safe. Research has been done in this area (see Appendix A.1) by the University of Toronto. The University of Toronto study showed that in order to avoid backdrafting, the maximum depressurization created by the air exhausting equipment was limited to 6 Pascals. The additional negative pressure caused by stack effect is not included in this depressurization limit.

4.3 The City of Edmonton Requirements

In addressing the requirement for the provision of sufficient make-up air to prevent backdrafting as set out in Article 6.2.3.12.(1) in the 1985 Alberta Building Code and to meet the minimum one half air change per hour requirement as set out in Article 9.33.3.1 of the same code, the City of Edmonton is requiring a balanced ventilation system (see Appendix C) ie. what is exhausted must be supplied. In discussions with the author of this requirement, the following was ascertained.

1. The amount of ventilation air required to be supplied by the 1985 Alberta Building Code (ie. 1/2 air change per hour) in most cases will meet the City of Edmonton's requirement for a balanced system. Some diversity in the use of air consuming equipment is assumed by the City of Edmonton.

2. In the case of large air consuming equipment (ie. large fans, Jenn Air cookers, or central vacuum systems exhausting to outdoors) the City of Edmonton will require that the ventilation system be sized in accordance with the extra demand.

The intent of the above requirement is to ensure that no backdrafting will occur and, is in effect, the City of Edmonton's interpretation of what constitutes "a sufficient quantity of make-up air" needed to avoid backdrafting as set out in Article 6.2.3.12.(1) of the 1985 Alberta Code.

The City of Edmonton also requires that applicants for heating and ventilation permits provide the following information (see Appendix C):

1. Volume of the dwelling (cubic metres)
2. L/s required
3. Type of System
4. Type of air-using equipment (manufacturer and capacity)

The purpose of item #4 above is to determine the quantity of air that would be exhausted if all air exhausting equipment was operating at the same time. Knowing how much air is exhausted would then lead to a determination of how much air must be supplied to maintain a balanced ventilation system. Caution should be exercised in applying the information in item #4 because the capacity of a fan varies with the pressure losses in the duct system connected to it. It also depends on the difference in pressure between the fan suction (house) and the fan discharge (outdoor). This indoor - outdoor pressure difference in turn depends on the house leakage area and losses in any make-up air ducts. The actual ventilation rate will usually be much less than the sum of the nominal exhaust fan capacities.

4.4 Natural Gas Installation Code CAN/CGA-B149.1-M86

Article 5.3.1 (see Appendix C) of the above code states that an outside combustion/dilution air supply duct to air appliances shall "terminate within one foot (300 mm) above and within two feet (600 mm) horizontally from, the burner level of the appliance having the largest output".

The size of the combustion/dilution air duct shall be sized in accordance with Table 5.2.2A of the above code (see Appendix C). The intent of these Articles is to ensure a source of fresh air to the burner so that in the event of vent reversal, the burner will take in fresh air and not combustion products. This reduces the potential for CO production.

4.5 Standata 85-DI-017 and Standata 85-DI-017R1

Standata 85-DI-017 (no longer in effect)
Standata are procedural approval memos issued by the Building Standards Branch of Alberta Labour. Standata 85-DI-017 provided two acceptable methods by which combustion and ventilation air could be provided for in typical new Alberta housing (see Appendix C).

Method One
Method one called for a combined combustion air and ventilation duct from the outside to be connected to the cold air return of a furnace. In addition, a combustion air duct was connected to the supply duct of the furnace and terminated open-ended in the room containing the combustion appliances.

Method Two
Method two called for two separate outdoor air intakes, one for combustion air and one for ventilation air. The combustion air duct terminated in a cylindrical container in the same room as the combustion appliances. The ventilation air duct connected to the cold air return of the furnace.

Although, in both cases, the requirements for the size of the combustion air duct were given, no requirements were explicitly given for the size of the duct necessary to provide sufficient ventilation air.

Standata 85-DI-017 also did not provide any guidance on how to provide combustion air for solid fuel burning appliances such as fireplaces, stoves, and space heaters.

It also did not give guidance on how to provide ventilation air in the case where heating was accomplished by a boiler and a hydronic heating system.

Standata 85-DI-017 was therefore rescinded and replaced with a revised regulation (85-DI-017R1) to accommodate these requirements.

Standata 85-DI-017R1 (in effect October 1987 to October 1988)

The revised Standata 85-DI-017R1 (see Appendix C) is essentially Method #2 of the original Standata 85-DI-017 with the following additional provisions:

For the case of heating by boiler and a hydronic heating system the revised Standata 85-DI-017R1 provides for a method whereby ventilation air can be supplied. It also addresses the requirements for the provision of combustion air for fireplaces, stoves, space heaters and ranges burning solid fuel.

Both Standata 85-DI-017 and 85-DI-017R1, while providing for a ventilation air duct in their requirements, do not specify the quantities of ventilation air that must be supplied. A prudent home builder would realize that Standata 85-DI-017R1 must be read in conjunction with the 1985 Alberta Building Codes requirements, especially its requirement for one-half air change per hour ventilation air. However, the home builder, even after referring to all relevant codes, would still not be given specific guidance on how to provide sufficient make-up air to prevent backdrafting as required by Article 6.2.3.12.(1) of the Alberta Building Code (see Appendix C). Concerned parties are finding it difficult to comply with and enforce this requirement.

Implied in the requirement for sufficient make-up air to prevent backdrafting, and in the City of Edmonton's requirement for a balanced system, is the need for sufficient flow rates of outside air into the house such that the pressure difference between inside and outside air does not get large enough to initiate backdrafting. This means that the ventilation air duct must be sized such that the flowrate of air into the house prevents backdrafting down the chimney.

STANDATA 85-DI-017R1 has not provided guidance in the sizing of the ventilation duct except to require that it be sized for 1/2 ACH and has not identified an acceptable value for pressure difference between indoor and outdoor conditions.

4.6 Building Standards, Ministry of Housing, Ontario

The building standards authorities in Ontario have adopted the 1985 National Building Code's requirement for one-half air change per hour ventilation air.

4.7 Building Standards, British Columbia

This agency has adopted the 1985 National Building Code's requirement for one-half air change per hour ventilation air but is finding it difficult to enforce. They have issued an appendix to the B.C. Building Code aimed at providing concerned parties with guidance on how to comply with the code. In addition to the appendix they are also giving a series of ongoing seminars offering guidance and receiving suggestions on how to best comply with the code. Two basic systems are in use to supply ventilation air. In the lower mainland around Vancouver, where outdoor air temperatures are moderate enough that preheating ventilation air is not necessary, a simple outdoor air intake is sufficient to meet code requirements. In colder winter climates a ventilation supply system consisting of running an outdoor intake duct to the cold air return of the furnace is being employed.

4.8 Canadian Standards Association

The Canadian Standards Association is in the process of developing the new standard CAN/CSA-F326-M. The preliminary Standard F326-1-M 1989, Residential Mechanical Ventilation Requirements, defines requirements for the design, installation and compliance testing of ventilation systems for the provision of minimum controlled rates of outdoor air to single family dwelling units.

Clauses 5.1, 5.2, and 5.3 (see Appendix C) of this standard require that ventilation air be supplied on a continuous basis at rates not less than those called for in column 1 of Table 1, or 0.3 air changes per hour, whichever is greater. Unlike other codes discussed here, this standard specifies ventilation system pressure design requirements related to various types of combustion appliances.

Critics of this standard maintain that it is unnecessary and unreasonable to require that ventilation air be supplied on a continuous basis.

5.0 POTENTIAL METHODS CONSIDERED FOR DEMONSTRATION

5.1 Introduction

There are numerous methods of providing combustion air and ventilation air in a safe manner. The following section outlines a range of potential methods which could be applied in typical Alberta production housing. Consistent with the objectives outlined in Section 1.0, all the potential designs use simple exhaust fans installed in the bathrooms and kitchen as the primary method of ventilation. All, except one of the systems, use natural draft furnaces and hot water heaters.

Costs given represent incremental costs over the cost of a basic system with natural draft appliances, a ventilation duct to the furnace return air, and a separate combustion air duct. Costs are based on actual invoices from the trades involved, and include the costs for uncertainties and inefficiencies associated with new materials and non standard methods.

The potential methods considered during this project are listed below and described on the figures noted:

- Bucket Trap Combustion Air, with ventilation air to the return air duct (Figure 5.2). This is the "base case".
- Economizer System (Figure 5.3).
- Sealed Furnace Room (Figure 5.4).
- Induced Draft Fan (Figure 5.5).
- Blower Assisted (Figure 5.6).
- Multiple Intakes and Dampers (Figure 5.7).
- Uncoupled Appliances ie. appliances with air supply directly from outdoors (arrangement as for Figure 5.2).
- Bucket Trap Combustion Air, with a heat recovery ventilator for ventilation air.

5.2 Review of Potential Methods

A project review committee consisting of residential builders, heating contractors, an HVAC specialist, and building code officials was formed.

These eight designs were reviewed and evaluated by the committee with respect to the following criteria:

1. Cost-effective in terms of equipment, installation and operation.
2. Understandable by the industry.
3. Within the capabilities of local building practice.
4. Achievable using hardware which is widely available.
5. Reliable over time and operable by typical homeowners.

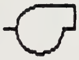
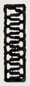
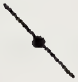
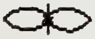
The assessment resulted in a decision to not test the following methods for the reasons outlined below:

1. Blower Assisted Ventilation and Combustion Air (Figure 5.6). The review committee felt that this solution does not meet the intent of the various codes because a separate combustion air duct is not provided. Also the committee felt that because the blower is interlocked with the gas valve the reliability of the system is in question.

2. Multiple intakes and dampers (Figure 5.7). This method was considered to be too expensive and complicated.

3. Uncoupled appliances. This method has already been demonstrated by other researchers and has been proven to work. Uncoupled appliances tend to be more efficient, but the incremental cost is approximately $1000.

4. Bucket trap combustion air with a heat recovery ventilator for ventilation air. This method has already been demonstrated and is not cost-effective at present energy costs in Alberta when used in conjunction with a forced air heating system (See Appendix A.5). Heat recovery ventilators seem more appropriate for hydronic heating systems.

	FURNACE BLOWER
	FURNACE FILTER
	FURNACE HEAT EXCHANGER
	MOTORIZED DAMPER
DPC	DIFFERENTIAL PRESSURE CONTROLLER
TS	TEMPERATURE SWITCH
HS	HUMIDISTAT
S	SWITCH
	EXHAUST FAN
C/A	COMBUSTION AIR
R/A	RETURN AIR
S/A	SUPPLY AIR
O/A	OUTSIDE AIR (VENTILATION AIR)

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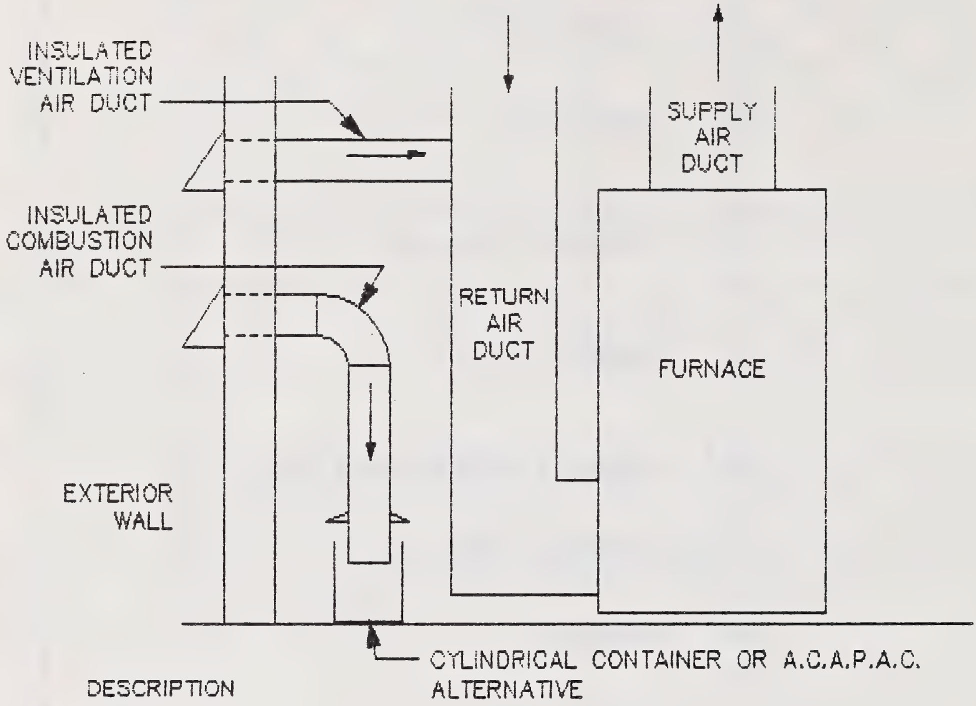
SYMBOL LEGEND FOR DRAWINGS

date: MARCH 1989 file no: 8815

figure no.

5.1


INSULATED VENTILATION AIR DUCT
INSULATED COMBUSTION AIR DUCT
EXTERIOR WALL
RETURN AIR DUCT
SUPPLY AIR DUCT
FURNACE
CYLINDRICAL CONTAINER OR A.C.A.P.A.C. ALTERNATIVE

DESCRIPTION

THIS POTENTIAL METHOD IS AS PER STANDATA 85-DI-017R

DISADVANTAGES

1- ADEQUATELY SIZED STAINLESS STELL OR ALUMINIZED HEAT EXCHANGER MAY BE REQUIRED TO ACCOMODATE 1/2 AIR CHANGE PER HOUR OUTSIDE AIR LOAD.
2- A LONG VENTILATION DUCT OR A VENTILATION DUCT WITH MANY ELBOWS MAY RESULT IN EXCESSIVE PRESSURE DROP AND THEREFORE DOWNDRAFTING.

ADVANTAGES

1- NO ADDITIONAL COST

2- APPROVED

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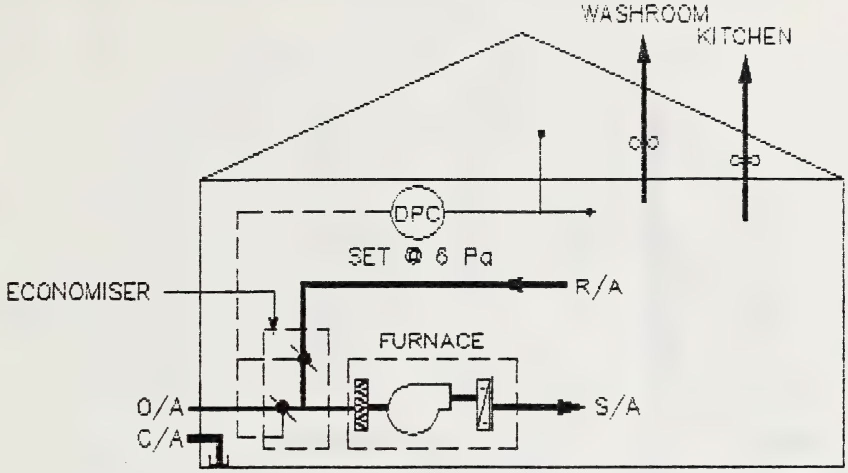
BUCKET COMBUSTION AIR
VENTILATION TO R/A DUCT
(AS PER STANDATA 85-DI-017R)
date: MARCH 1989 file no: 8815

figure no.
5.2



DESCRIPTION

VIA DAMPERS IN "MIXING TEE" THE DIFFERENTIAL PRESSURE CONTROLLER VARIES THE PROPORTION OF RETURN AIR AND OUTSIDE AIR DRAWN INTO THE FURNACE BY THE BLOWER. THE DAMPERS ALLOW MORE OUTSIDE AIR TO BE DRAWN IN WHENEVER THE HOUSE IS SLIGHTLY DEPRESSURIZED BY AN EXHAUST FAN OR OTHER APPLIANCE. THIS PREVENTS SIGNIFICANT DEPRESSURIZATION IN THE HOUSE. THIS EXTRA OUTSIDE AIR IS PREHEATED BY THE FURNACE.

DISADVANTAGES

1– COST ($ 3,986)

2– POTENTIAL CORROSION OF HEAT EXCHANGER IN WINTER. 34 KW FURNACE DELIVERS APPROX. 470 L/S WHICH LIMITS O/A TO 68 L/S WITH MILD STEEL HEAT EXCHANGER. ALUMINIZED HEAT EXCHANGER WOULD OVERCOME O/A LIMIT FOR APPROX. $140

3– WOULD REQUIRE HEAT EXCHANGER TO BE SIZED TO HANDLE MAXIMUM EXHAUST LOAD

ADVANTAGES

1– FREE COOLING IN SUMMER

2– BETTER VENTILATION IN SUMMER (RELIEF DAMPER IS NOT REQUIRED AS WINDOWS COULD BE USED TO RELIEVE IN SUMMER)

3– WOULD AUTOMATICALLY ACCOMMODATE MAKE–UP AIR REQUIREMENTS FOR ALL EXHAUSTING APPLIANCES (EG. FIREPLACES)

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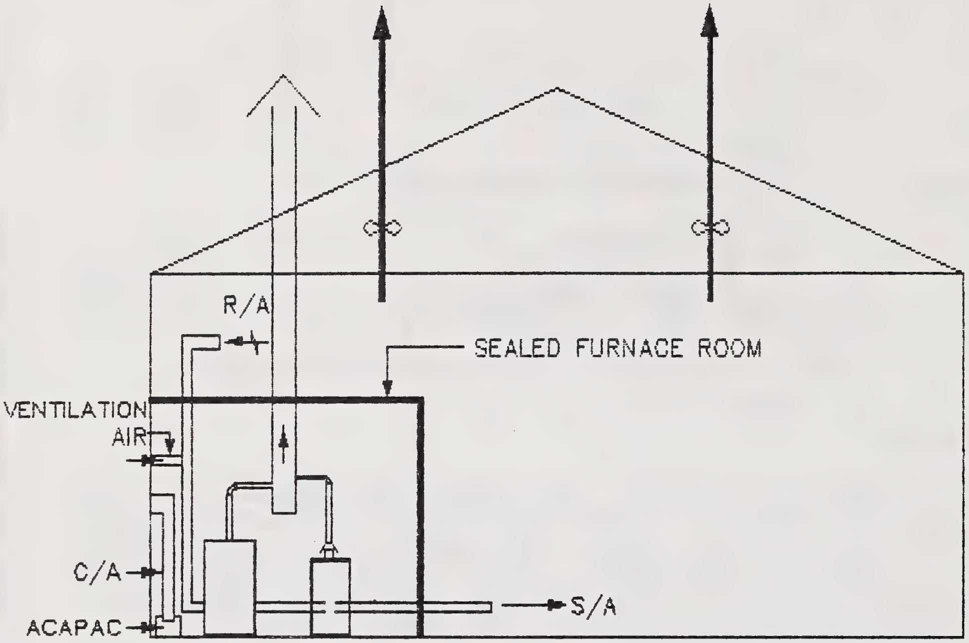
ECONOMIZER
(MIXING TEE SYSTEM)

date: MARCH 1989 file no: 8815

figure no.
5.3



DESCRIPTION

FURNACE AND HOT WATER HEATER ARE LOCATED IN A AIR TIGHT (SEALED) ROOM ISOLATED FROM THE HOUSE PRESSURE CHARACTERISTICS. SUFFICIENT OUTSIDE AIR IS ADMITTED INTO THE SEALED FURNACE ROOM IN ORDER TO ENSURE THAT NO BACKDRAFTING OF THE CHIMNEY OCCURS.

DISADVANTAGES

1– COST ($ 1,275)

2– EFFECTIVE AIR SEALING DIFFICULT TO ACHIEVE

ADVANTAGES

1– PREVENTS DOWNDRAFTING BY UNCOUPLING APPLIANCES FROM HOUSE.

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SEALED FURNACE ROOM

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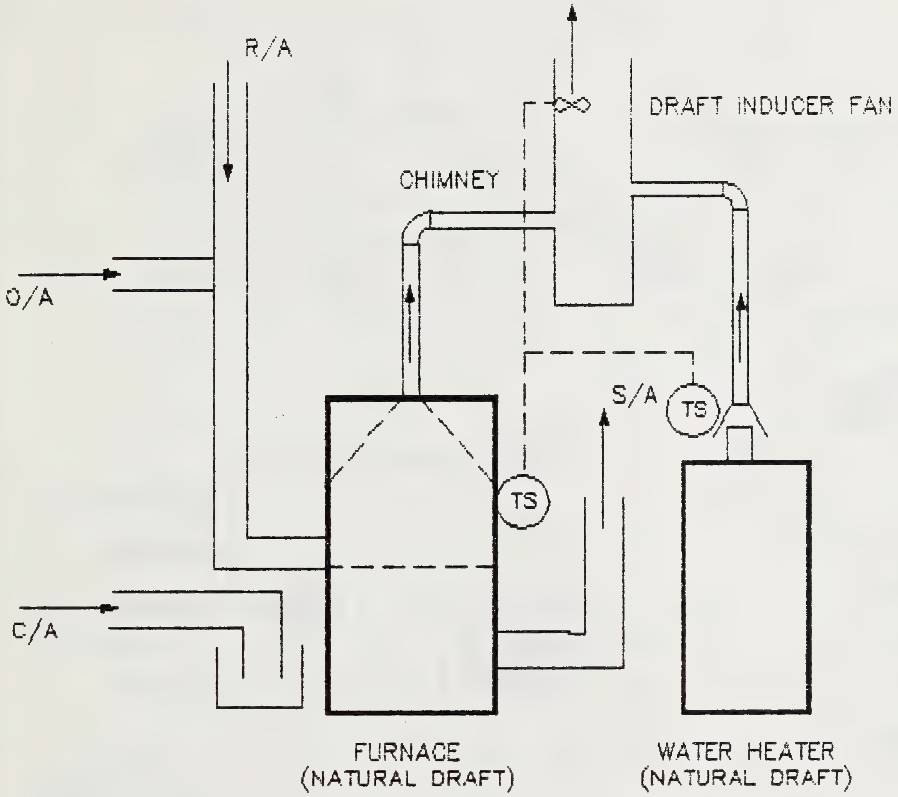
figure no. 5.4



— FAN OPERATED FROM THERMAL SWITCHES

DESCRIPTION

THIS POTENTIAL METHOD COMBINES THE REQUIREMENTS OF STANDATA 85-DI-017R WITH THE INSTALLATION OF AN INDUCED DRAFT FAN LOCATED IN THE FLUE. THE PURPOSE OF THE FAN IS TO STOP BACKDRAFTING AS SOON AS IT IS DETECTED BY EITHER TEMPERATURE SWITCH.

DISADVANTAGES	ADVANTAGES
1– COST APPROX. $500	1– PREVENTS BACKDRAFTING

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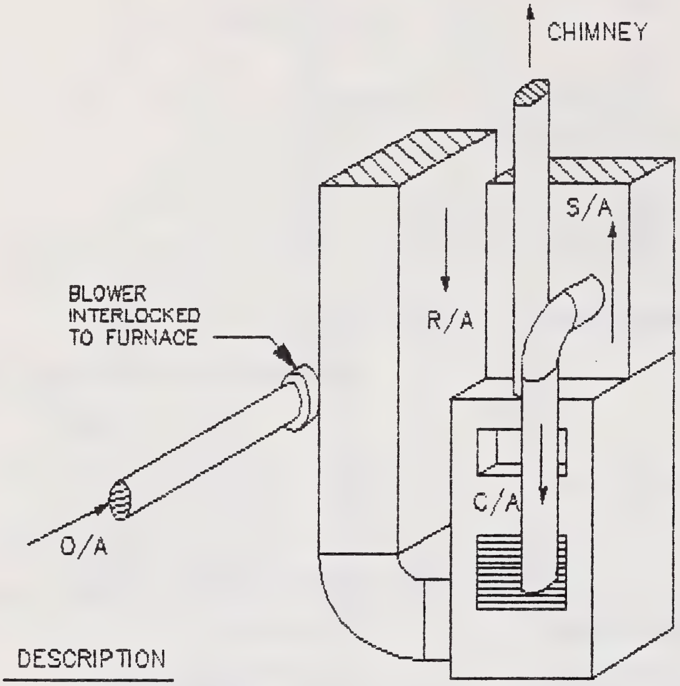
INDUCED DRAFT FAN IN CONJUNCTION
WITH STANDATA 85-DI-017R1

date: MARCH 1989 file no: 8815

figure no.
5.5



DESCRIPTION

THIS SYSTEM USES A PRESSURIZATION FAN TO FORCE AIR INTO THE HOUSE. A SUPPLY DUCT FROM THE WARM AIR PLENUM LEADS TO NEAR THE COMBUSTION CHAMBER INLET, THE PURPOSE OF WHICH IS TO PARTIALLY PRESSURIZE THE BASEMENT.

DIADVANTAGES

1– AIR DELIVERY IS GREATLY RESTRICTED WHEN FAN FAILS

ADVANTAGES

1– PROVIDES CONSTANT DELIVERY OF AIR WHEN OPERATING WHICH COULD BE MATCHED TO AIR NEEDS OF HOUSE

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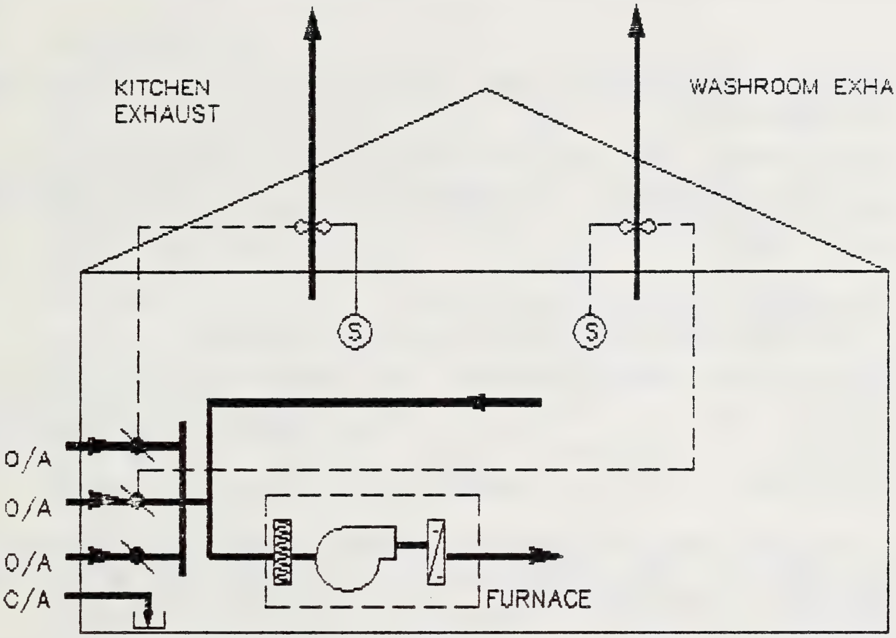
BLOWER ASSISTED AIR SUPPLY

date: MARCH 1989 file no: 8815

figure no.
5.6



DESCRIPTION

THIS POTENTIAL METHOD UTILIZES DIFFERENT SIZE OUTDOOR AIR DUCTS EACH WITH A MOTORIZED DAMPER AND ALL CONNECTED TO A COMMON PLENUM. EACH MOTORIZED DAMPER IS INTERLOCKED TO A PARTICULAR PIECE OF EXHAUST EQUIPMENT. WHEN THE EXHAUST EQUIPMENT BEGINS OPERATING THE DAMPER OPENS TO ALLOW MAKE-UP AIR INTO THE RETURN AIR DUCT OF THE FURNACE.

DISADVANTAGES

1- COSTS

2- MULTIPLE WALL PENETRATIONS

3- MULTIPLE CONTROL INTERLOCKS

ADVANTAGES

1- SHOULD PREVENT BACKDRAFTING

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MULTIPLE INTAKES AND
DAMPERS WITH SEPARATE C/A

date: MARCH 1989 file no: 8815

figure no.

5.7

The assessment resulted in a decision to test the following four approaches:

1. Bucket Combustion Air, Ventilation to Return Air (Figure 5.5)

   This method was approved for further study, in order to provide a baseline for comparison of the other systems, and because it appeared to meet the evaluation criteria.

2. Economizer Mixing Tee System With Separate Combustion Air (Figure 5.2)

   The review committee felt that this solution would be fairly costly, therefore most appropriate for larger houses. If this solution is widely implemented, commercial production could result in lower costs as discussed in Section 6.5.1.

   The system was designed to filter out wind effects on the outdoor pressure sensor so that an average outdoor pressure could be sensed.

   Technically this is the best solution and it provides the added benefit of allowing free cooling, as described in Section 6.5.

3. Sealed Furnace Room (Figure 5.3)

   This solution uncouples the furnace and hot water heater from the pressure regime inside the house but it may be difficult and expensive to achieve a sealed room. Protection would also have to be provided to protect against water system freezing.

4. Induced Draft Fan Installation In Conjunction with STANDATA 85-DI-017R1 (Figure 5.4)

   This system provides protection against backdrafting of naturally aspirating appliances through the addition of a simple and inexpensive fan on the side of the flue pipe.

6.0 DEMONSTRATION OF FOUR SELECTED SYSTEMS

6.1 Introduction

The following section describes the four systems that were selected for demonstration and testing. The systems were installed in four "Rosewood II" model houses built by Reid-Built Homes. The mechanical contractor was Dyand Mechanical Systems Ltd. The Rosewood II is a split level house with 101 square metres of plan area, 155 square metres of living area, and 202 square metres of total area including basement.

The demonstration systems were installed in accordance with drawings provided by Sunton Engineering Ltd. Field tests were conducted to verify that the installed systems performed as designed.

6.2 Summary of Field Measurements

Indicator dots which change colour due to heat when backdrafting occurs were installed at the draft diverter of each gas fired appliance (See Photo 6.1). Initial pressure differential readings between indoor and outside and air flow readings for outdoor air, combustion air and exhaust air were recorded by Sunton Engineering Ltd. Additional readings, using more accurate measuring equipment, were recorded by Servall Mechanical Services Ltd. These field measurements are summarized in Table 6.1.

Ongoing monitoring of the economizer and draft inducer demonstration systems was undertaken by Howell Mayhew Engineering Ltd. This monitoring also evaluated the operation of a bucket combustion air system by examining the draft inducer system during normal (non-backdrafting operation).

As shown by the test data in Table G.1, none of the washroom exhaust fans delivered its rated nominal capacity. The fans ranged from a low of 20% to a high of 90% of their rated nominal capacity. This is probably due to reduced capacity resulting from long duct runs. The kitchen range hoods all exhausted more air than their nominal rated capacity. The performance of these fans would probably be reduced considerably if the building envelopes were tighter.

Fan depressurization tests were used to determine the leakage area of two of the test houses (the induced draft installation and the economizer installation). The test results are described more fully in Section 9.4. The houses had a equivalent leakage area of approximately 0.07 square meters (26cm x 26cm). The sum of the exhaust fans flow is approximately 120 L/s, or approximately 0.9 ACH, which would result in a 6 Pa negative pressure if it was all drawn in through the envelope leakage openings. Because of this, it is very unlikely that these houses will backdraft, even with all the exhaust fans in operation. With the help of the "leaky" building envelopes, the houses have no problem satisfying the requirement of having the capability of one half air change per hour.

TABLE 6.1
SUMMARY OF FIELD MEASUREMENTS

	Bucket Combustion Air	Economizer	Sealed Furnace Room	Draft Inducer
Combustion Air (L/s)	13.7	18.4	19.4	21.0
Outside Air (L/s)	77.9	-	41.0	41.0
Range Hood (L/s)	85.4	79.4	79.2	90.0
Washroom #1 (L/s)	4.7	12.7	14.2	17.9
Washroom #2 (L/s)	17.5	21.2	21.2	19.8
Washroom #3 (L/s)	-	-	-	19.8
Total Exhaust (L/s)	107.6	113.3	114.6	147.5
Total Exhaust (ACH)	0.79	0.83	0.84	1.08
Differential Pressure(1) (Pa)	-2.50	-3.70	-5.00	-5.00

TEST CONDITIONS: Furnace on, all exhaust fans on, fireplace off (damper closed), dryer off.

(1) indoor - outdoor pressure differential at the basement level, including stack effect.

Rated capacities: Range Hood - 75.5 L/s,
Washroom Fans - 23.6 L/s each.

6.3 Bucket Combustion Air, Ventilation to Return Air

.1 Installation

The bucket combustion air system was installed in accordance with Standata 85-DI-017R1. It is shown schematically in Figure 5.2. As the base case, the incremental cost of this system is nil.

.2 Operating Tests

Measurements by Servall Mechanical indicate an airflow rate of 13.7 L/s through the combustion air duct. This is slightly less than the 15 L/s expected for the 31 kW furnace based on the calculations in Section 3.4.

The maximum fresh air flow through the fresh air duct occurred with both washroom fans on, the kitchen range hood on and the furnace blower on. The maximum air flow measured was 77.9 L/s with a 2.5 Pa negative pressure in the basement. The sum of the airflows through the exhaust fans was 107.6 L/s. This flow corresponds to a maximum air change rate of 0.79 air changes per hour. The difference between the airflow through the outside air duct and the airflow through the exhaust fans (29.7 L/s or 0.22 ACH) is probably leaking through the building envelope due to the pressure difference between the inside and the outside of the building.

The washroom exhaust fans were exhausting 20% and 74% of their nominal rated capacity. The kitchen range hood was exhausting 113% of its nominal rated capacity.

.3 Discussion

This system is designed to provide combustion air for the gas fired appliances only. Air required for fireplaces is now required to be supplied by a separate duct terminating in the fireplace or the room in which the fireplace is located. Air required by exhaust fans, clothes dryers and other appliances is supposed to be supplied by a separate insulated duct connected to the furnace return air duct. The ducts for all these requirements were installed in the demonstration system. Corrugated flexible insulated ducts were used, 152 mm diameter for combustion air, and 178 mm diameter for ventilation air.

A "tight" building envelope coupled with upgraded exhaust systems to ensure the capability of one half air change per hour could result in backdrafting of natural draft gas fired appliances since building depressurization would likely exceed 6 Pa. Furnace manufacturers have responded by installing thermal cut out switches in the furnace draft diverters. Photograph 6.1 shows the sensor located across the draft diverter. The cutout switch will stop furnace backdrafting by shutting down the furnace when hot gases are sensed at the draft hood. They must be manually reset to restart the furnace. These cut out systems could result in building freezeups and water damage, particularly if the occupants leave the building unattended for long periods in cold weather, without noticing that the furnace has cut out.

The "bucket" combustion air system presently required by the Alberta Building Code is sized to provide air for the natural draft gas fired appliances only. If the fresh air duct is not sized large enough to accommodate the required half air change, and if the building envelope has a leakage area less than 0.07 square meters, thermal cutout problems can be expected. For example, the house studied requires 70 L/s of fresh air to provide one half air change per hour. To limit the pressure drop through a 178 mm diameter duct to 6 Pa (the commonly accepted value at which backdrafting may occur), the maximum allowable duct run is 9.1 metres of straight smooth duct. Bends, elbows and the corrugated flexible duct commonly used have a high pressure drop and would significantly reduce the allowable duct run, as discussed below.

The test house has 4.57 meters of corrugated straight duct and two elbows. Each elbow has an equivalent length of 1.61 meters. The effective length of the fresh air duct is approximately 7.8 meters. With entrance and exit losses of 8 Pa, the effective pressure drop through the duct when it is delivering 1/2 air change per hour (70 L/s) is 17.4 Pa. If all of the air exhausted by the exhaust fans (118 L/s) were delivered via the fresh air duct, a 41 Pa pressure drop would result. This would present backdrafting problems if the building envelope was tightly sealed. In view of this, caution should be exercised when sizing the fresh air duct required by the Alberta Building Code. As the house leakage area decreases, the size of the fresh air duct must be increased, if this system is to be used. However, a large make-up air duct connected to the furnace return air plenum is not desirable, for the following reason: It must be sized large enough to balance the exhaust flow when the furnace blower is not running. Because of this, it would allow excessive quantities of fresh air to be drawn in when the furnace blower is operating.

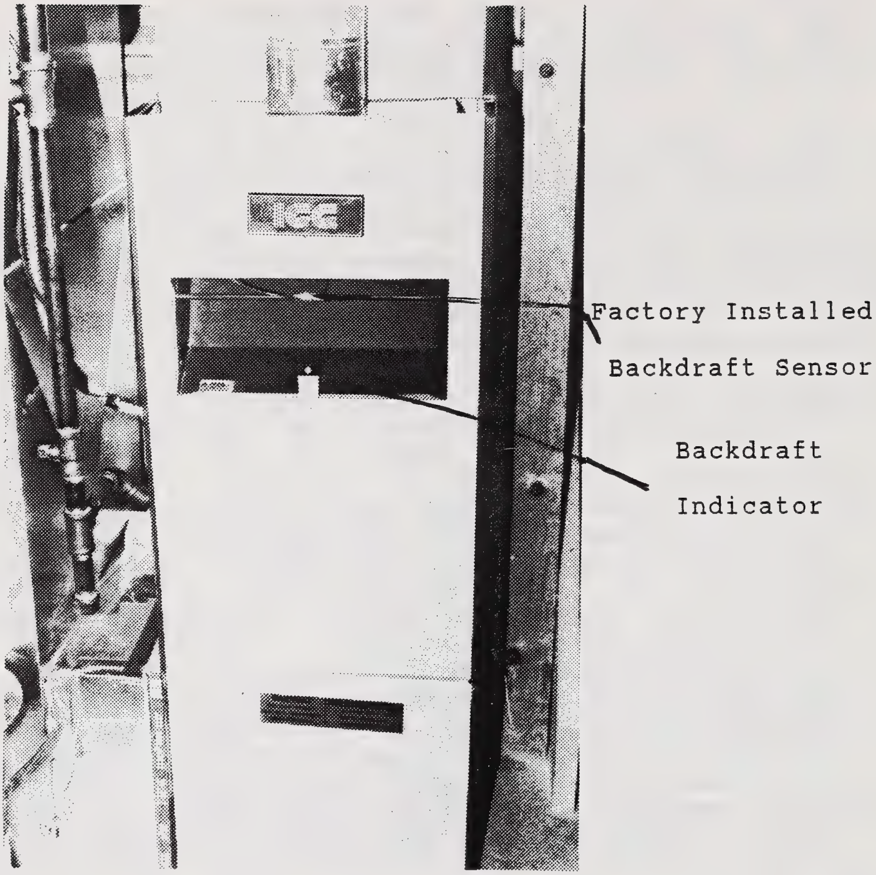


Photo 6.1

Temperature Sensor in Draft Diverter

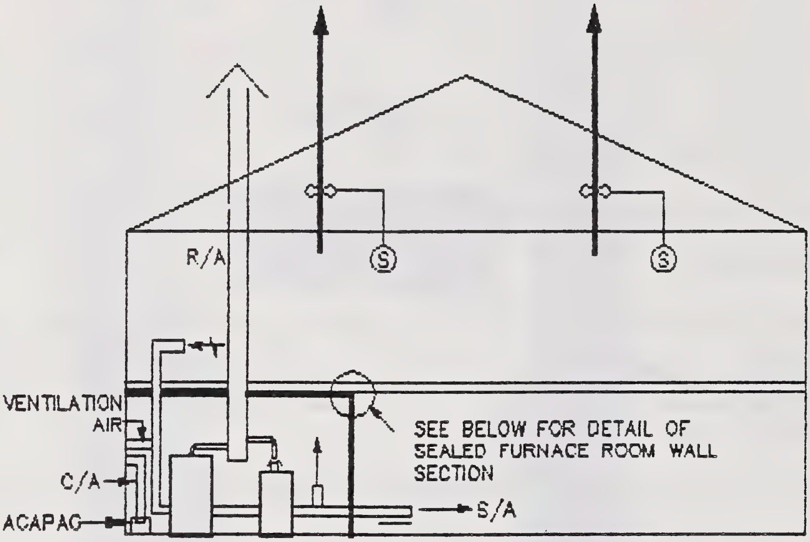
6.4 Sealed Furnace Room

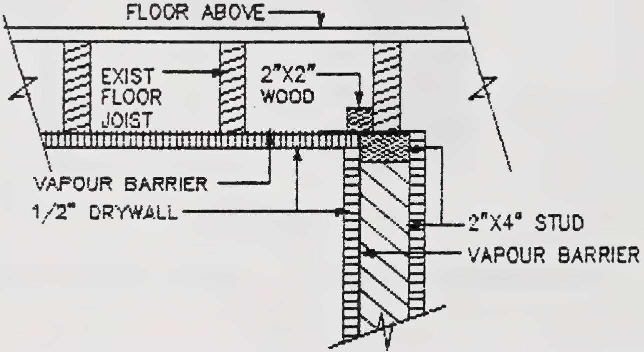
.1 **Installation**

The sealed furnace room was intended to be installed in accordance with Figure 6.1. The contractors actually chose to install a separate furnace room ceiling rather than drywalling the underside of the floor joists as shown on the drawing. The space between the furnace room ceiling and the main floor of the building accommodated ductwork. Ductwork penetrations were supposed to be sealed at the furnace room ceiling but were not well sealed, as the photographs show. Photographs 6.2 and 6.3 show exterior views of the sealed furnace room, and photographs 6.4 and 6.5 show the B-vent and combustion air duct penetrations through the furnace room ceiling.

An ACAPAC combustion air duct damper was installed on the combustion air duct to prevent freezing of the domestic water heater when the furnace is not running. This is shown in photographs 6.6 and 6.7. See Appendix J for detailed information on the ACAPAC.

The installed cost of the sealed furnace room was $ 1,275.





DETAIL OF RECOMMENDED WALL AND CEILING CONSTRUCTION FOR SEALED FURNACE ROOM (N.T.S.)

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SEALED FURNACE ROOM SCHEMATIC AND
WALL SECTION DETAIL

date: MARCH 1989 file no: 8815

figure no.
6.1

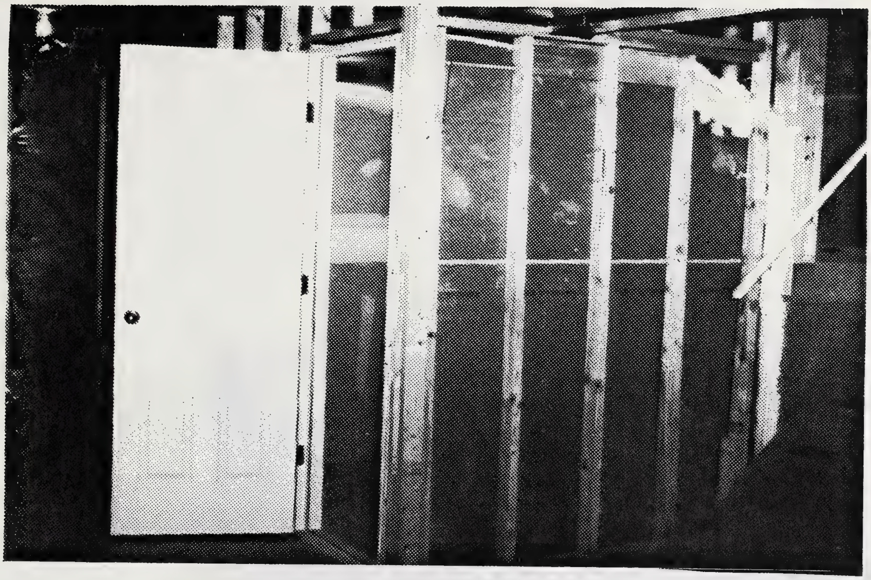


Photo 6.2

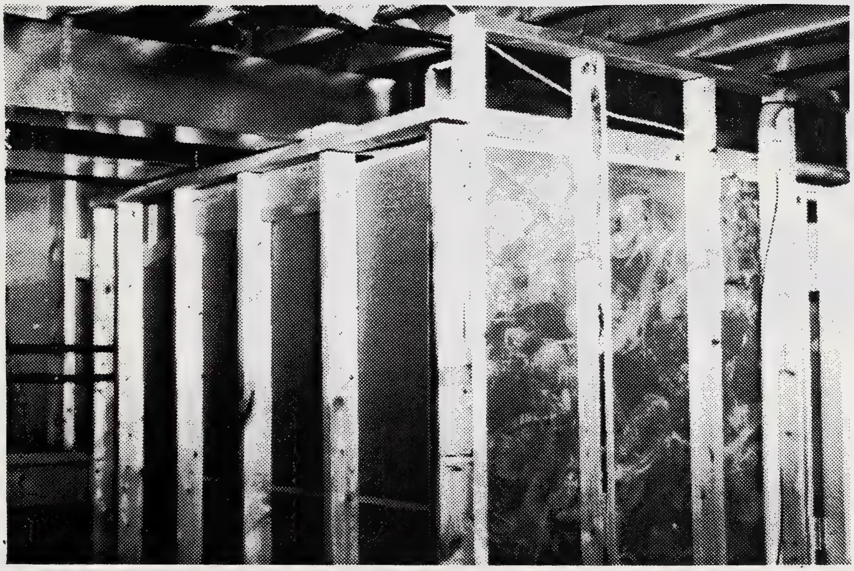


Photo 6.3

Sealed Furnace Room

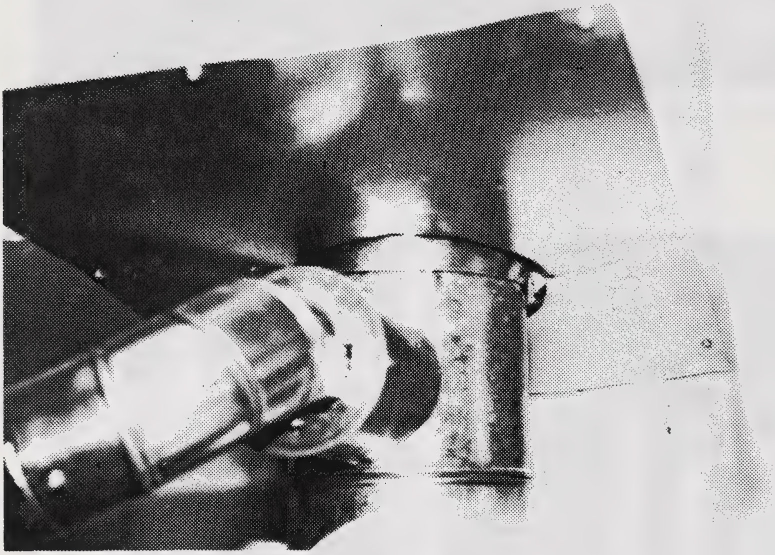


Photo 6.4

B-Vent Penetration

Sealed Furnace Room

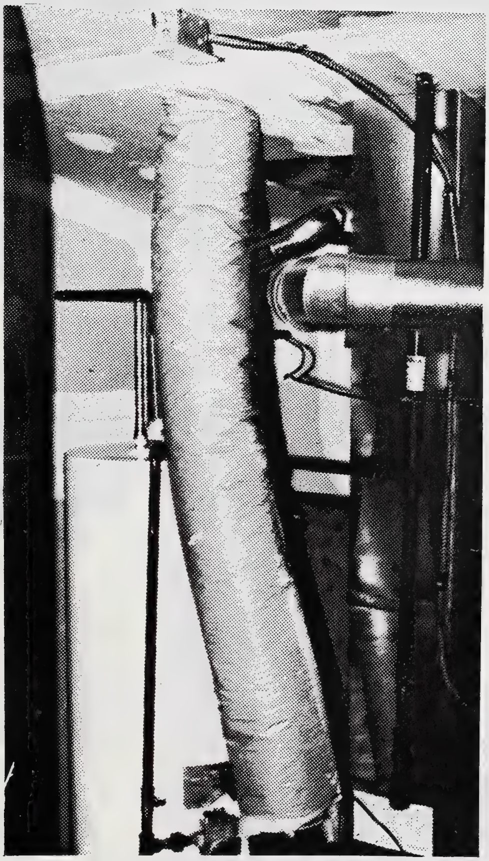


Photo 6.5

Combustion Air Duct Penetration

Sealed Furnace Room

Photo 6.6

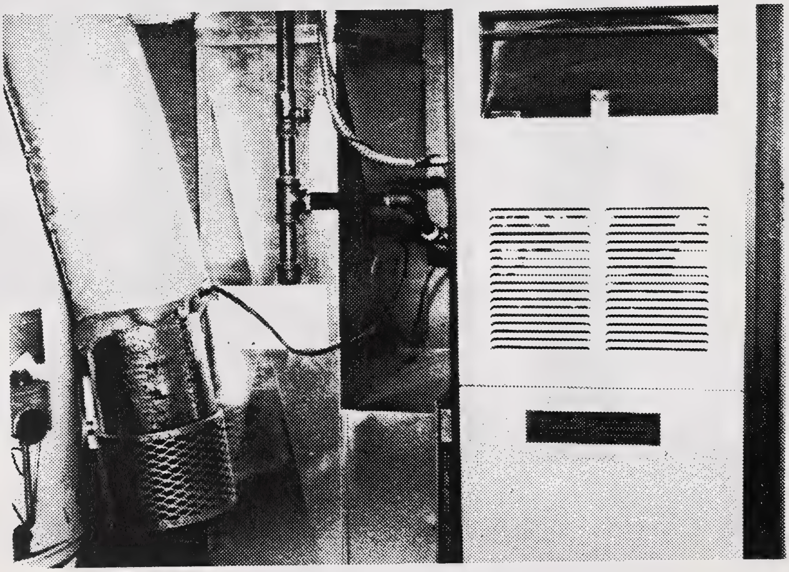


Photo 6.7

ACAPAC Installation

Sealed Furnace Room

.2 Operating Tests

There was no detectable pressure differential across the furnace room wall when all exhaust fans and the furnace blower were operating. With the ACAPAC opening temporarily sealed to prevent combustion air from entering the sealed furnace room, and all fans in operation, there was still no measurable pressure differential between the furnace room and the rest of the building, which indicates that, due to air leakage, the sealed furnace room was completely ineffective in isolating the combustion appliances from the rest of the house. The ACAPAC functioned correctly; manually forcing the ACAPAC damper to close and shut the furnace off.

The airflow through the combustion air duct was 19.4 L/s. The expected airflow for the 31 kW furnace was 15 L/s. The maximum fresh air flow through the fresh air duct occurred with both washroom fans on, the kitchen range hood on, and the furnace blower on. The maximum air flow measured was 41 L/s with a 5.0 Pa negative pressure in the building basement. The sum of the airflows through the exhaust fans was 114.6 L/s. This flow corresponds to a maximum air change rate of 0.84 air changes per hour. The difference between the airflow through the outside air duct and the airflow through the exhaust fans (73.6 L/s or 0.54 ACH) is probably leaking through the building envelope due to the pressure difference between the inside and outside of the building.

The washroom exhaust fans were exhausting 60% and 90% of their nominal rated capacity. The kitchen range hood was exhausting 105% of its nominal rated capacity.

.3 Discussion

The installers were aware that this was a prototype installation, and in view of this, an installation that would be better sealed than any mass produced installation was expected. This seems not to have been the case. Photographs 6.8, 6.9 and 6.10 show leaks in the installation we inspected.

The sealed furnace room does not appear to be a viable concept because of the difficulty of achieving a seal. Further, if a verification process (eg. air leakage test) is required for each installation, it would significantly increase the cost.

Photo 6.8

Leak at Combustion

Air Duct Penetration

Sealed Furnace Room

Photo 6.9

Leak at Wall Joint

Sealed Furnace Room

Photo 6.10

Leak Between Wall and Floor

Sealed Furnace Room

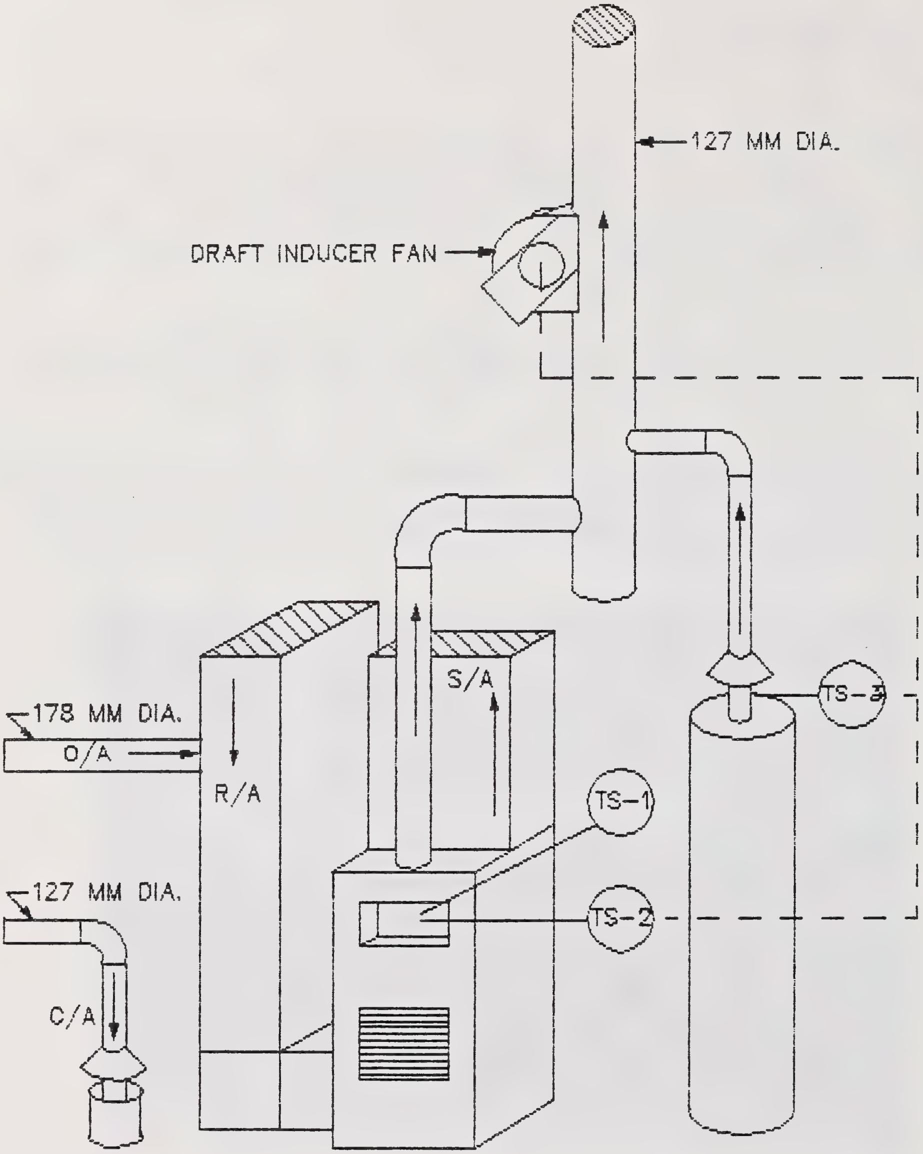
6.5 Induced Draft Fan

.1 Installation

The induced draft fan was installed on the common B-vent as shown in Figure 6.2. Temperature switches installed in the draft diverters of both the gas fired appliances start the fan if backdrafting occurs. The induced draft fan is shown in photographs 6.11 and 6.12. The installed cost of the induced draft fan was $457.

Photographs 6.13 and 6.14 show the temperature sensors installed in the draft diverters of the furnace and water heater to initiate operation of the draft inducer fan.

The induced draft fan is started when the temperature at the draft diverter exceeds 73.3 degrees C. The furnace cutout switch stops the furnace when the temperature at the draft diverter exceeds 178 degrees C. The indicator dots change colour at 66 degrees C.



TS-1 - FACTORY INSTALLED FURNACE CUTOUT - SETPOINT 178°C
TS-2 - SETPOINT 73°C
TS-3 - SETPOINT 73°C

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DRAFT INDUCER FAN ARRANGEMENT
IN CONJUNCTION WITH
STANDATA 85-DI-017R

date: MARCH 1989 file no: 8515

figure no.
6.2

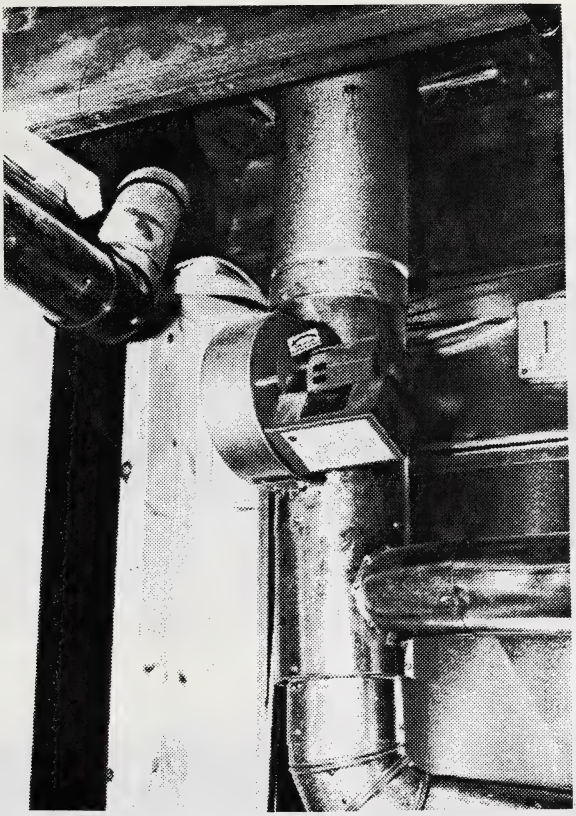


Photo 6.11

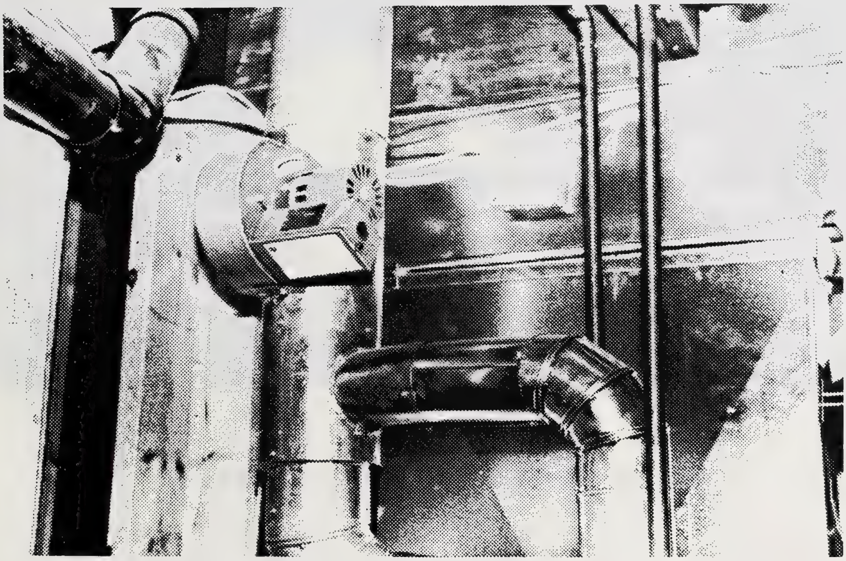


Photo 6.12

Induced Draft Fan

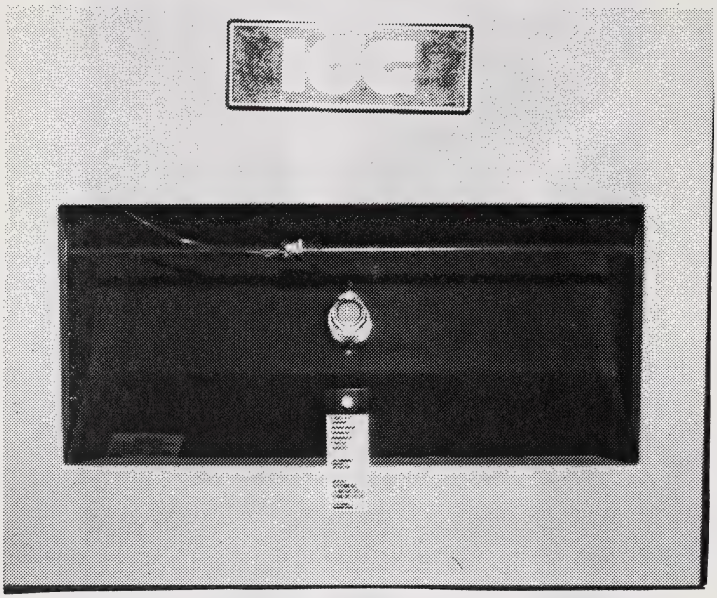


Photo 6.13

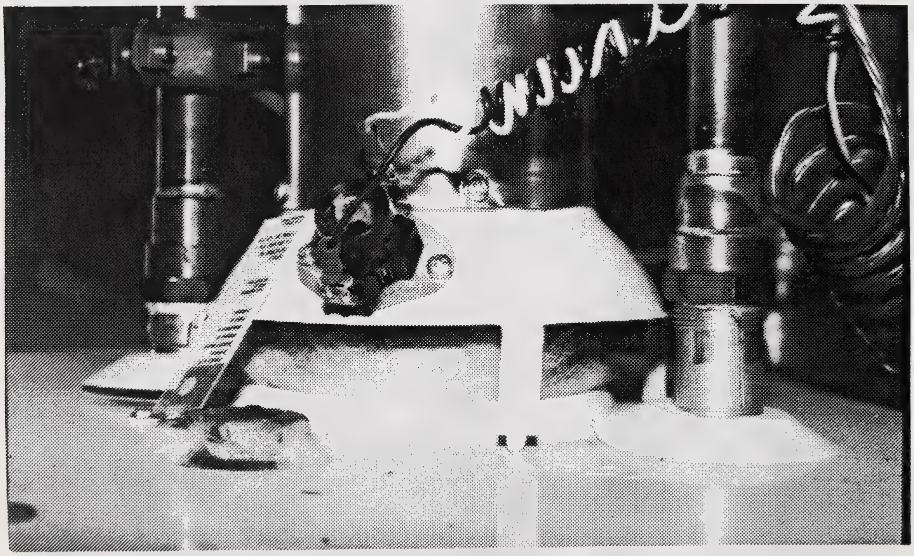


Photo 6.14

Sensors for Induced Draft Fan

.2 Operating Tests

Measurements by Servall Mechanical Services Ltd. provided the following results:

- The airflow through the combustion air duct was 21 L/s. The expected airflow for the 31 kW furnace was 15 L/s.

- The maximum fresh air flow through the fresh air duct occurred with all three washroom fans on, the kitchen range hood on, and the furnace blower on. The maximum airflow measured was 41 L/s with a 5.0 Pa negative pressure in the building basement.

- The sum of the airflows through the exhaust fans was 147.5 L/s. This flow corresponds to a maximum air change rate of 1.08 air changes per hour. The difference between the airflow through the outside air duct and the airflow through the exhaust fans (106.4 L/s or 0.78 ACH) is probably leaking through the building envelope due to the pressure difference between the inside and outside of the building.

- The washroom exhaust fans were exhausting 76%, 84%, and 84% of their nominal rated capacity. The kitchen range hood was exhausting 128% of its nominal rated capacity. The operation and effectiveness of the draft inducer was not tested since the installed exhaust equipment was not capable of initiating spillage.

.3 Discussion

The induced draft fan is designed to produce a pressure differential of approximately 11 Pa when delivering 36 L/s and installed on a 127 mm B-vent. It is capable of preventing backdrafting through atmospheric gas fired appliances. The induced draft fan does nothing to ensure adequate ventilation rates in housing.

With the advent of factory installed thermal cutout switches in the draft diverters of modern furnaces, this solution might be considered redundant. However, it should prevent possible freezeups associated with the furnace cutouts initiated by the factory installed backdraft prevention switches, since the induced draft fan would normally stop backdrafting before the cutout stopped the furnace. In addition, it would prevent backdrafting of the water heater, as well as the furnace.

The induced draft fan is supplied, with a pressure switch to initiate fan operation (photograph 6.15). This is a good alternative to the thermal switches that we installed in the appliances' draft diverters. We chose to use temperature switches as this was the method of control reported in "Residential Combustion Venting Failure, A Systems Approach" (See Appendix A.4). In retrospect, the pressure switch is preferable because the installation is simpler and cheaper.

As the induced draft fan operation is fully automatic, no special homeowner instructions are necessary.

The gas code does not clearly permit or prohibit the use of a draft inducer used in this manner, although it does not permit it to be used "in place of " a natural draft vent in a one or two family dwelling. There are also some concerns about its effect on the burner flame and on proper venting of other appliances such as fire places. For these reasons, the CGA B149 Committee on the Installation Codes for Natural Gas/Propane Burning Appliances and Equipment should be requested to decide on the acceptability of the system used in this project.

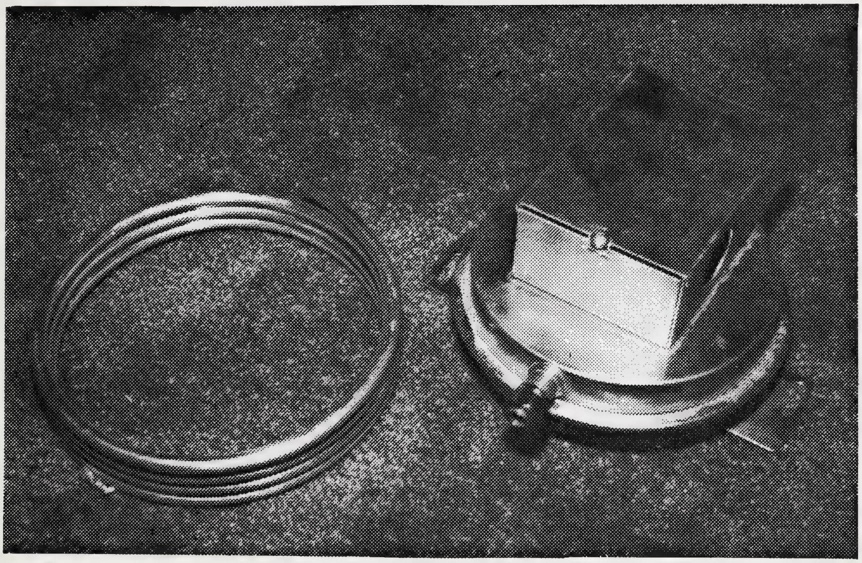


Photo 6.15

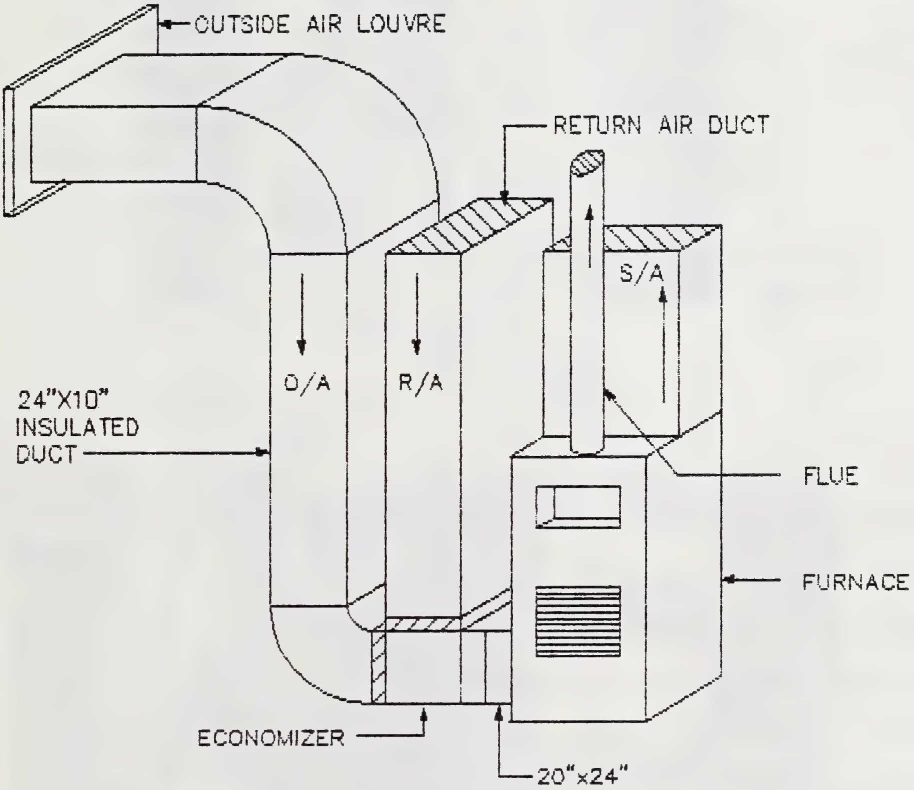
Unused Pressure Sensor for Induced Draft Fan

6.6 Economizer (Mixing Tee)

.1 Installation

Figure 6.3 shows the general arrangement of the economizer system. The economizer controls, schematic and sequence of operation are shown in Figure 6.4. The total installed cost of the prototype system was $ 3,986 (see Appendix G). A combustion air duct was included with this system to comply with existing codes. The combustion air duct and individual fresh air ducts to fireplaces could be eliminated in future installations if the building code authorities agree. We calculate that the cost of the mass produced systems could be reduced to $2,275. Additional potential equipment reductions such as combustion air ducts are not listed. We have not reduced the projected installed cost due to these potential reductions because they must be approved by code authorities or are not standard on every house.

Photographs 6.16 and 6.17 show the economizer installation. Photo 6.18 shows the mixing box with the cover plate removed. Note that the damper motor was not installed at this time. Photo 6.19 shows the furnace with the cover plate removed. The adjustable discharge air temperature controller is visible to the right of the main gas valve. Turning the knob decreases or increases the temperature of the discharge air when the thermostat is not calling for heat. Photograph 6.20 shows the discharge air temperature sensor which sends signals to the controller shown in Photograph 6.19. Photograph 6.21 shows the insulated fresh air duct. Photographs 6.22 and 6.23 show the fresh air intake louver.



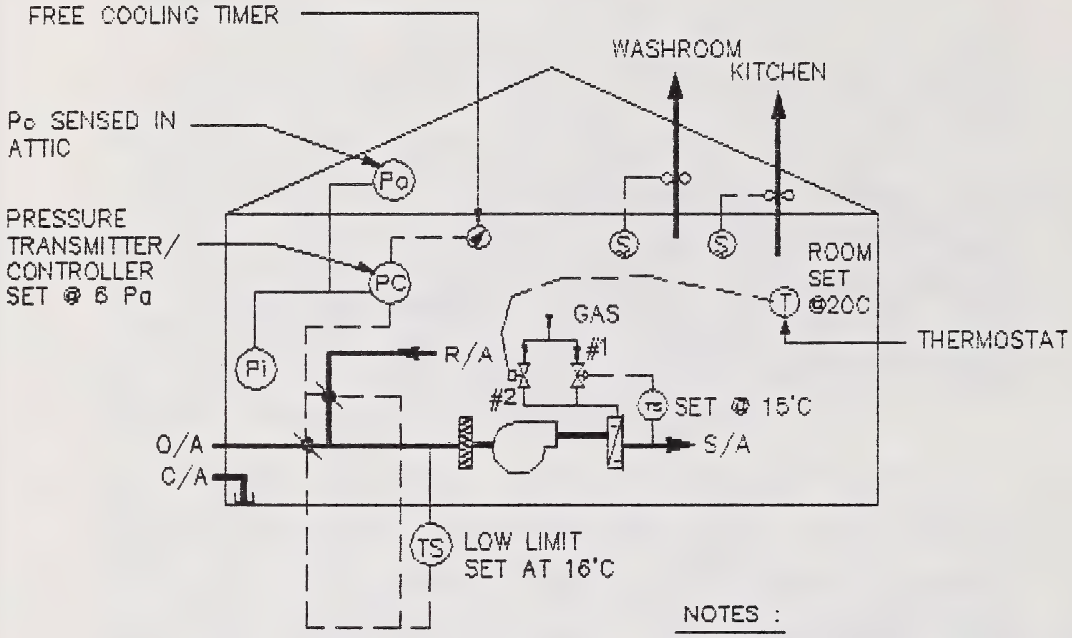
SUNTON
ENGINEERING

ECONOMIZER (MIXING TEE) ARRANGEMENT

date: MAY, 1988 file no: 8815

figure no.

6.3



NOTES :

1– SET POINTS ARE ADJUSTABLE
2– C/A DUCT PROVIDED TO SATISFY CODE REQUIRMENTS

SEQUENCE OF OPERATION

FURNACE FAN RUNS CONTINUOUSLY

FURNACE DISCHARGE THERMOSTAT MODULATES GAS VALVE #1

ROOM THERMOSTAT CYCLES GAS VALVE #2

DIFFERENTIAL PRESSURE TRANSMITTER/CONTROLLER MODULATES DAMPERS

FREE COOLING TIMER OPENS O/A DAMPER FULLY AND CLOSES R/A DAMPER

LOW LIMIT CONTROL OPENS R/A DAMPER AND CLOSES O/A DAMPER

SUNTON
ENGINEERING

ECONOMIZER (MIXING TEE) SCHEMATIC

date: MARCH 1989 file no: 8815

figure no.
6.4

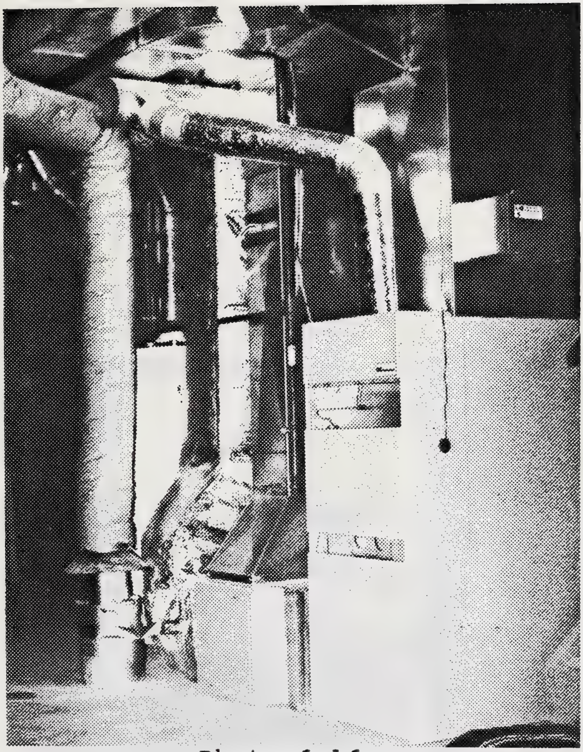


Photo 6.16

Combustion Air   Outside Air

Photo 6.17

Economizer (Mixing Tee)

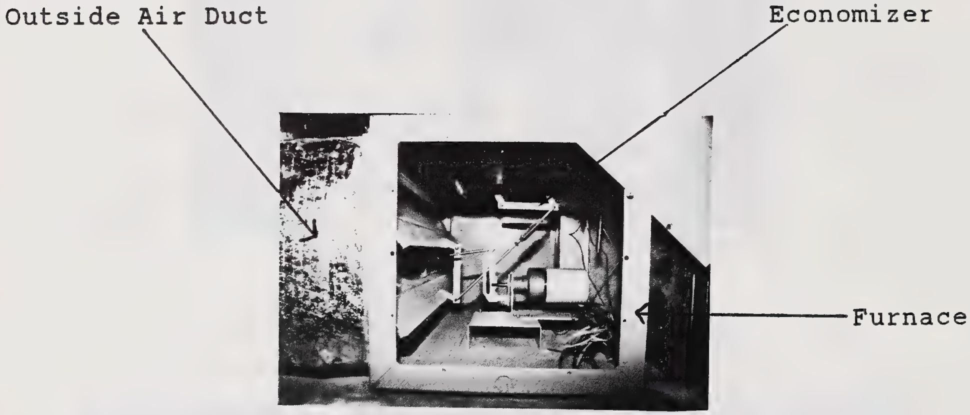


Photo 6.18

Mixing Box

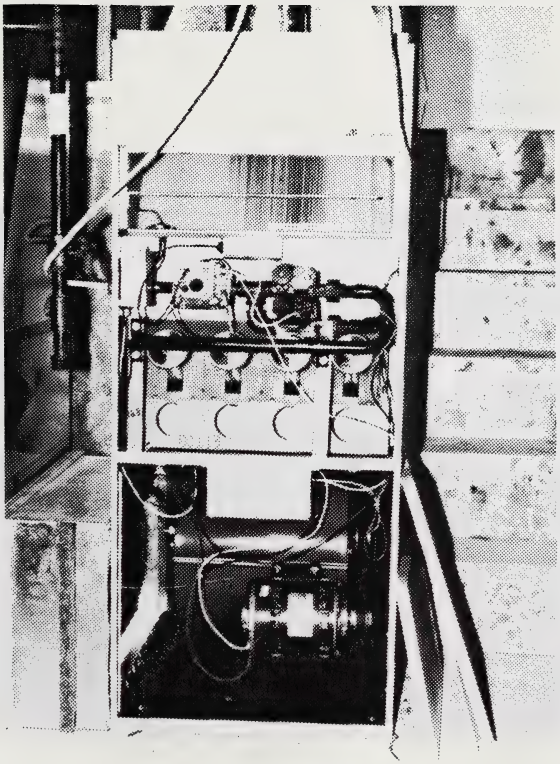


Photo 6.19

Economizer System

Furnace

(with access covers removed)

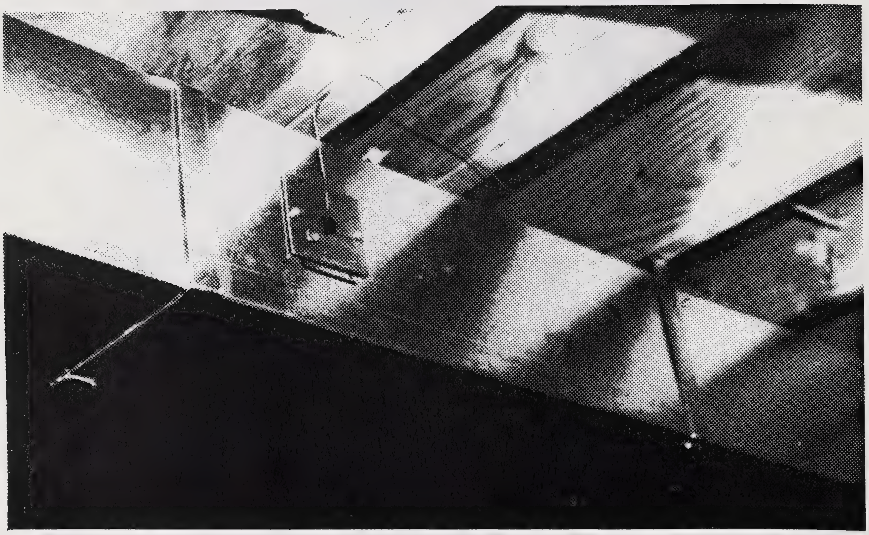


Photo 6.20

Discharge Air Temperature Sensor

Economizer System

Photo 6.21

Insulated Fresh Air Duct

Economizer System

Photo 6.22

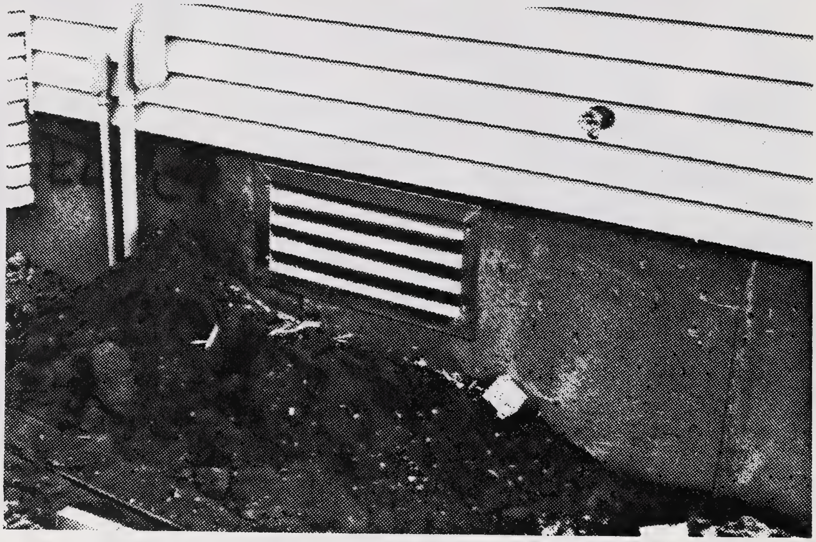


Photo 6.23

Fresh Air Intake Louver

Economizer System

.2 Owner Operating Instructions

The economizer ventilation system is designed to automatically provide the make-up air quantity from outside that is required to replace air exhausted from the building. There are four adjustments that are not available on normal residential heating and ventilating systems.

A discharge air temperature adjustment knob is located behind the upper cover of the furnace. It is calibrated from 1 to 10. Increasing the setting to a higher number increases the minimum supply air temperature delivered by the furnace. Setting number 10 will result in air being supplied at a minimum of approximately 21°C. Set this control as low as possible consistent with comfortable conditions in the building. It may be necessary to turn this control down in summer and up in winter.

A differential pressure control setpoint is located adjacent to the electrical breaker panel. It is calibrated from three to nine pascals negative pressure. Setting this control at 3 Pa negative will result in increased fresh air delivered to the house. This will result in a higher natural gas bill. Setting the controller at 5 or 6 Pa will reduce the fresh air delivered to the house. This will reduce the natural gas bill. We recommend setting this control as high as possible consistent with acceptable air quality in the building.

The control should be set in the coldest weather and left at that setting. Setting this control at too high a value (ie. close to 7 Pa) could result in furnace backdrafting. If this occurs, the furnace will shut off due to the factory safety control. The white dot installed at the furnace draft diverter may also turn black. If the furnace shuts off readjust the pressure controller to a lower number, remove the top panel on the furnace, and press the reset button. The furnace will restart. If the dot on the draft diverter has turned black, replace it with the spare provided. Once the correct setting is established, future adjustment should be unnecessary.

A "free cooling" timer has been provided to increase comfort. In the summer, when it is cooler outside than it is inside the house, free cooling is available. Open one or two windows in the house and set the timer for one to six hours. The furnace will introduce 100% fresh air to the house as long as the timer is running. If the timer is inadvertently initiated during cold weather, the system will automatically shut the outside air off to prevent freezing. This is accomplished by the low limit controller located on the duct on the left hand side of the furnace. This controller should be set at about 15°C.

.3 Operating Tests

Our initial operating tests were conducted during windy conditions. As a result, the readings were not considered accurate. We conducted additional tests while calibrating the differential pressure controller. We found that we could achieve differential pressures of over 6 Pa negative with all exhaust fans, the clothes dryer, and the fireplace in operation. Resetting the controller allowed us to maintain any setting between 3 and 6 Pa negative. No backdrafting of the atmospheric gas fired appliances occurred. The outside air dampers responded to appliances being turned on and off. The differential pressure setpoint was maintained under all modes of operation. The low limit controller shut the outdoor dampers and opened the return air dampers when the mixed air temperature fell below the setpoint. The free cooling timer operated as designed.

The sum of the airflows through the exhaust fans was 113 L/s, or an air change rate of 0.83 ACH. The washroom fans were exhausting 54% and 90% of their nominal rated capacity. The kitchen range hood was exhausting 113 % of its nominal rated capacity.

.4 Discussion

The economizer system operation exceeded our expectations. The system maintained the differential pressure setpoint very precisely. No "hunting" of the mixing box dampers was evident.

Of the systems considered under this project, the economizer system is the only "total system" approach to ensuring adequate ventilation under all operating conditions. It is also effective at preventing backdrafting. The drawback is the installed cost.

With the economizer approach to ventilation and the prevention of backdrafting. No differentiation need be made between fresh air required for combustion or ventilation. The system automatically provides the minimum amount of fresh air based on demand. The system automatically accommodates additional air required by retrofits of additional exhaust devices. For example, a darkroom exhaust fan or "Jenn-air" cooker would automatically be provided with additional fresh air make-up if these appliances were installed subsequent to the construction of the house.

The fresh air quantities delivered to the house can be adjusted by the homeowner by changing the remote setpoint of the differential pressure controller. This allows the homeowner to select the combination of air quantity and energy usage that is acceptable. The occupant also has control by switching on or off the exhaust fans.

The system is capable of providing up to 3.5 air changes per hour of fresh air when in the free cooling mode, with windows open for relief, as discussed in Section 6.5.2.

The minimum supply air temperature can be chosen by the homeowner.

The differential pressure controller will prevent backdrafting and eliminate the possibility of freezing the building due to furnace cutout in response to the factory installed backdraft prevention switch.

The economizer system could eliminate the need for combustion air ducts for natural draft gas fired appliances and fireplaces. The permission of the authorities having jurisdiction over various building and equipment codes would be required to accomplish this.

The prototype economizer system requires continuous fan operation to ensure adequate make-up air flow. Assuming that the economizer system was set up to draw about the same electrical consumption as a standard system (4.2 amps), that the economizer system operates for 3.65 times the number of hours as a standard system, and that the cost of electricity is 5 cents/kWh, the incremental cost of continuous operation over intermittent operation would be about $160/year. This cost could be reduced if the economizer system is shut off during the summer months.

The smallest furnace with a suitable gas train available for this project was a 37.5 kW unit. It comes equipped with a larger motor which operates at 7.5 amps instead of the 4.2 amp motor supplied with the 31 kW standard furnace. As a result it costs an additional $334/year to operate continuously, compared to non-continuous operation of a standard furnace. In addition, the occupants have found the air velocity excessive when the thermostat is not calling for heat. These effects were subsequently minimized by installing a two-speed motor on the furnace. The motor operates on high speed only when the thermostat calls for heat. On low speed, the furnace blower delivers 40-50% less air. Since current draw is proportional to the cube of the volume, the fan would draw approximately 1 ampere on low speed. In addition, due to the larger heating capacity of the furnace it would operate for fewer hours at high speed than a standard furnace would operate. Under these conditions, the system would cost approximately $70/year more for electricity than a standard furnace.

7.0 COMPUTERIZED MONITORING

7.1 Introduction

The focus of the computerized monitoring was on the collection and analysis of performance data on three of the four demonstrated ventilation strategies detailed in Section 5.2 in order to provide conclusions and recommendations on reliability, workability, operating cost and resistance to backdrafting. The economizer and draft inducer demonstration systems were chosen which allowed for an evaluation of the operation of the bucket combustion air system by examining the draft inducer system during normal (non-backdrafting) operation.

7.2 Monitoring System

The monitoring system installed in each house consisted of an IBM-XT compatible computer interfaced with a Sciemetric Model 8082 data acquisition system. The monitoring task was defined using COPILOT, the data acquisition, management and analysis software developed by Howell Mayhew Engineering. Photographs 7.1 and 7.2 show parts of the monitoring system during installation.

The parameters being measured are listed in Table 7.1.

Table 7.1: PARAMETER AND SENSOR LIST

Parameter	Sensor
1. Building envelope pressures	Pressure transducer
a) Pressure difference across ceiling b) Pressure difference in basement at height of furnace draft hood	
2. Backdrafting and spillage	Thermocouple
3. Status of induced draft fan	Voltage sensor
4. Air-flows	Flow station plus pressure transducer
a) Flow of combustion air b) Flow of return air c) Flow of ventilation/makeup air in house with Economizer system	

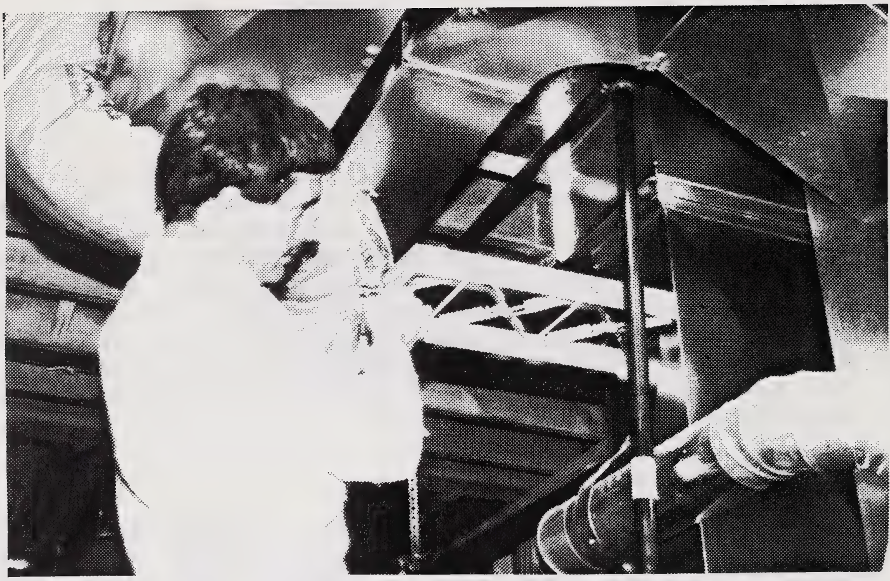


Photo 7.1

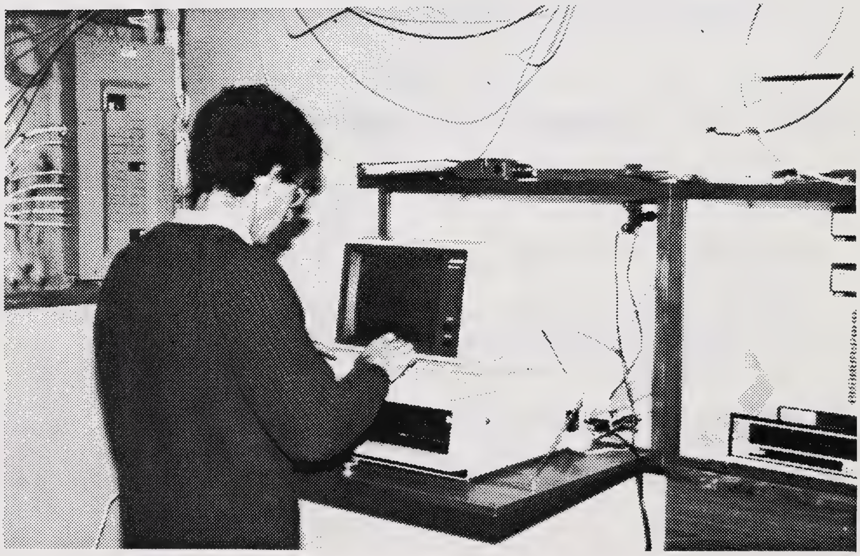


Photo 7.2

Monitoring System (Draft Inducer House)

5. Air-flow temperatures	Thermocouple
a) Makeup air entering at hood	
b) Makeup air entering return air	
c) Combustion air entering at hood	
d) Combustion air leaving bucket	
e) Return air from house	
f) Return air entering furnace	
g) Supply air leaving furnace	
h) Supply air entering a room	
6. Relative humidity of exhaust air	Capacitance sensor

7.3 Sensor Description and System Measurements

The sensors used to measure the different parameters and the rationale for taking these measurements are given below.

1. Building Envelope Pressure Measurements

The Modus T-001B differential pressure transducer was chosen to measure positive and negative pressures across the building envelope. The range of this transducer was -0.1 to +0.1 inches of water (-25 Pa to +25 Pa). The purpose of these measurements was to determine the potential for backdrafting and the pressure at which it occurred.

2. Backdrafting and Spillage Measurements

A thermocouple was installed at the draft hood of the furnace to detect the occurrence of backdrafting and/or spillage.

3. Operation of the Induced Draft Fan

A voltage status sensor was connected to the induced draft fan to determine the number of times the fan turned on and the length of time it operated. This data, combined with pressure information, was to be used to determine the effectiveness of this device in reversing backdrafting.

4. Air-flow Measurements

Two types of pressure transducers were chosen for these measurements. An Environmental Control Technology Model LPTB low pressure transducer with a range of -0.25 to +0.25 inches of water (-63 Pa to 63 Pa) was specified to measure the flow through the furnace return air duct. The more sensitive and more expensive Modus T-001 pressure transducer with a range of 0.0 to 0.1 inches of water (0 to 25 Pa) was chosen to measure the much smaller air flows of 0 to 30 litres per second anticipated through the ventilation/makeup and combustion air ducts.

Flow measuring stations utilizing pitot tube arrays and manufactured by Conservation Energy Systems were used to produce the pressure outputs.

5. Air-flow Temperature Measurements

Thermocouples were used to measure air-flow temperatures. A teflon coated wire offering excellent moisture and very good abrasion resistance, and useful from -65 C to +204 C was chosen for this purpose.

Air-flow and air-flow temperature data was used to determine the quantity of outside air entering through the ventilation/makeup and combustion air ducts and to assist in evaluating the effect of this air on indoor comfort levels and energy consumption.

6. Relative Humidity Measurements

A General Eastern RH-2 ductmount relative humidity sensor was selected to provide an accurate measurement of indoor humidity levels. The sensor was mounted in the return air plenum and the data was used assist in the evaluation of indoor air quality and comfort levels.

8.0 ADDITIONAL TESTING AND MONITORING

To supplement the computerized monitoring, a number of one-time tests were conducted on each of the houses and additional information was gathered from the utilities and the homeowner.

8.1 Air Depressurization Testing

An air depressurization test was conducted by Howell Mayhew Engineering to determine the extent of the air leakage across the building envelope. This test provided the information necessary to predict air leakage rates through the building envelope under normal operating pressures and to allow for comparisons with other conventional houses.

8.2 Air Quality Monitoring

The purpose of this monitoring was to determine the effectiveness of the ventilation strategy in each house in providing adequate indoor air quality. To accomplish this task, formaldehyde and relative humidity levels were measured.

Formaldehyde levels were measured in February in the family room and in one bedroom of each house using formaldehyde dosimeters. The economizer system was not in operation at this time and, as a result, the dampers that control the supply of fresh air into the furnace return air plenum were taped shut. In this way, the only source of fresh air, other than natural infiltration, was the combustion air duct. The dosimeters and the test results were provided by ORTECH International.

Indoor relative humidity levels were monitored continuously by the computer.

8.3 Backdrafting Tests

A simplified backdraft test was carried out in each of the houses to determine the effectiveness of the economizer system in preventing backdrafting, the susceptibility of the bucket combustion air system to backdrafting and the ability of the induced draft fan to reverse a backdrafting flue.

The blower door apparatus used for the depressurization testing was also used in this test to establish the negative indoor pressure required to induce backdrafting.

8.4 Economizer "Free-Cooling" Test

In addition to supplying fresh air to the house and preventing backdrafting, the economizer system can be used as a cooling system when it is cooler outside the house than it is inside. The system is equipped with a five hour timer. As long as the timer is running, dampers in the economizer mixing box are completely open, blocking the furnace return air plenum and introducing 100% fresh air into the house from the outside.

The test was conducted during July and August. The homeowner was asked to maintain a written record of the use and operation of the economizer cooling cycle including the date, the time and duration of the timer operation, the temperature indicated by the house thermostat, and the furnace fan setting (high or low). The computer monitoring system provided additional indoor and outdoor temperature measurements.

8.5 House Energy Consumption

Monthly gas and electric consumption records were collected from the utilities to assist in evaluating the cost performance of each ventilation strategy.

8.6 Homeowner Interviews

The homeowners were interviewed during each site visit regarding thermal comfort and drafts, control and operating ease of the ventilation system and satisfaction with heating bills.

9.0 MONITORING RESULTS AND DISCUSSION

9.1 Schedule of Monitoring Activities

Construction and equipment installation delays combined with equipment failures resulted in reduced periods of continuous monitoring for some of the parameters outlined in Section 7.3. The schedule of activities presented in Table 9.1 will assist in clarifying the timing of monitoring tasks that were carried out.

Table 9.1: SCHEDULE OF MONITORING ACTIVITIES

House	Date	Activity
Economizer	DE 14	Monitoring system installed and commissioned, economizer not operational
	DE 30	Homeowners moved in
	JA 09	Air depressurization test conducted
	FE 07	Formaldehyde test initiated
	JN 07	Monitoring system temporarily shut down
	JN 27	Economizer system operational, two speed furnace motor installed
	JL 19	Monitoring system turned on, backdraft test initiated, and monitoring of economizer cooling cycle commenced
	SE 25	Monitoring system removed
Induced Draft	DE 16	Monitoring system installed and air depressurization test conducted
	DE 31	Homeowners moved in and monitoring system commissioned
	FE 17	Formaldehyde test initiated
	FE 20	Induced draft fan installed, monitoring sensor connected
	AL 30	Computerized monitoring completed
	SE 28	Backdraft test conducted, monitoring system removed

9.2 Backdrafting and Spillage

House pressure was measured in order to determine the potential for backdrafting in each of the houses and to record envelope pressures if backdrafting occurred.

Naturally aspirating gas appliances are the heating appliances most susceptible to the spillage of combustion products. Research that has been carried out in this area(1,4,6) has shown that negative pressures in excess of 6 to 10 Pa can cause spillage and backdrafting. Fortunately, the products of the complete combustion of natural gas, carbon dioxide and water, are relatively harmless and prolonged spillage that has resulted in life-threatening situations is very rare.

Of much greater concern are the combustion products from wood burning fireplaces, especially dying fires, where carbon monoxide is one of the combustion products. Unacceptable exhaust spillage from an open fireplace can occur when a negative indoor pressure of 10 Pa exists.

Analysis of the data collected from the draft hood thermocouple on each furnace and the induced draft fan status sensor indicated that neither backdrafting nor significant spillage occurred in either house during the monitoring period. This was supported by the fact that the "backdrafting dots" installed by Sunton Engineering at the draft hood of the furnace and hot water heater had not turned black. Note that, as indicated in Table 9.1, the induced draft fan was not installed until February 20 and the economizer system was not operational until June 27.

1. The Economizer System

The fact that backdrafting did not occur in the economizer house is particularly significant since, without the economizer system operational, there was effectively no makeup or ventilation air line into the house. In addition, the fireplace of this house, which was not fitted with glass doors, was used on a daily basis until the end of March. During this time, the furnace fan was operating on a continuous high speed. Indications are that indoor negative pressures were neutralized by air infiltrating through the building envelope and the combustion air duct.

Under these house operating conditions, the daily averaged pressure across the ceiling typically ranged from 3 Pa to 1 Pa. The maximum ceiling pressure recorded was 7.0 Pa and the minimum was -4.5 Pa. The daily averaged basement pressure at the level of the furnace draft hood ranged from -1 Pa to -3 Pa. Basement pressures less than -10 Pa were recorded on only 5% of the days monitored. The minimum basement pressure recorded was -13.6 Pa. This was evidently a short term, wind-induced condition, as explained below.

2. The Bucket Combustion Air/Induced Draft System

The operation of the bucket combustion air/induced draft house differed from the economizer house in that the fireplace was not used during the monitoring period and the furnace fan was not run continuously. In addition, this house was equipped with a ventilation/makeup air duct to the return air plenum.

Under these operating conditions, the daily averaged pressure across the ceiling fluctuated less than the economizer house and was typically 3 Pa. The maximum ceiling pressure recorded was 10.1 Pa and the minimum was -1.6 Pa. The average basement pressure at the level of the furnace draft hood was also between -1 Pa and -3 Pa. Basement pressures less than -10 Pa were recorded on 9% of the days monitored with a minimum recorded basement pressure of -22 Pa.

The large negative pressures that were occasionally recorded in each of the houses were wind induced and resulted from the single point measuring technique used for this project. These anomalies can be reduced by measuring pressure on all sides of the house and averaging the values.

9.3 Backdraft Testing

1. The Economizer System

The backdraft test conducted on the economizer system by Howell-Mayhew Engineering (HME) indicated that, when the furnace was not firing, backdrafting could be induced when the house was depressurized to approximately -6.0 Pa. Field testing carried out by Servall Mechanical Services (SES) found that a pressure of approximately -7.5 Pa in the basement could be achieved with all exhaust fans and the clothes dryer in operation. These measurements indicate, therefore, that the potential for backdrafting does exist.

To determine the ability of the economizer to reverse a backdrafting flue, backdrafting was induced with the furnace firing and the economizer system off. Once backdrafting had occurred (approximately -15 Pa), the economizer system was turned on and within 60 seconds the indoor pressure had increased to -5 Pa and the flue was no longer backdrafting.

The backdraft indicator installed by Sunton Engineering correctly indicated that backdrafting had occurred during these tests. The backdraft sensor supplied with the furnace, however, did not shut the furnace down once backdrafting had occurred.

2. The Bucket Combustion Air/Induced Draft Fan

The backdraft test conducted on this house by HME indicated that, when the furnace was not firing, backdrafting was also induced when the house was depressurized to approximately -6 Pa. Field testing carried out by SES found that a pressure of approximately -7.5 Pa in the basement could be achieved when both washroom fans, the kitchen range hood and the clothes dryer were operating. The fireplace was not in operation for this testing. These results indicated that the potential for backdrafting also exists in this house.

Initial attempts to test the induced draft fan system revealed that the furnace backdraft temperature sensor would shut down the furnace before the induced draft fan began operating. Temperature measurements taken at the sensor controlling the operation of the induced draft fan revealed that this sensor had not been installed directly in the flow of backdraft air. When temperatures at the furnace sensor were 165°C, temperatures at the induced draft fan sensor were only 77°C. Both of these sensors are shown in Photograph 6.13. The furnace is shown under normal and backdrafting conditions, respectively, in Photographs 9.1 and 9.2.

Testing was completed by operating the induced draft fan manually. To determine the fan's ability to reverse a backdrafting flue, backdrafting was induced with the furnace firing and the induced draft fan off. The house was depressurized and backdrafting occurred at approximately -20 Pa. The induced draft fan was turned on but was not capable of reversing the backdraft at this level of depressurization before the built-in furnace sensor stopped the furnace (less than one minute). Accordingly, the house pressure was reduced and, at -15 Pa, the induced daft fan was able to reverse the backdrafting condition in approximately 10 seconds. These performance values for the draft inducer agree with test results obtained from other researchers(4). The backdraft indicator installed by Sunton Engineering correctly indicated that backdrafting had occurred during these tests.

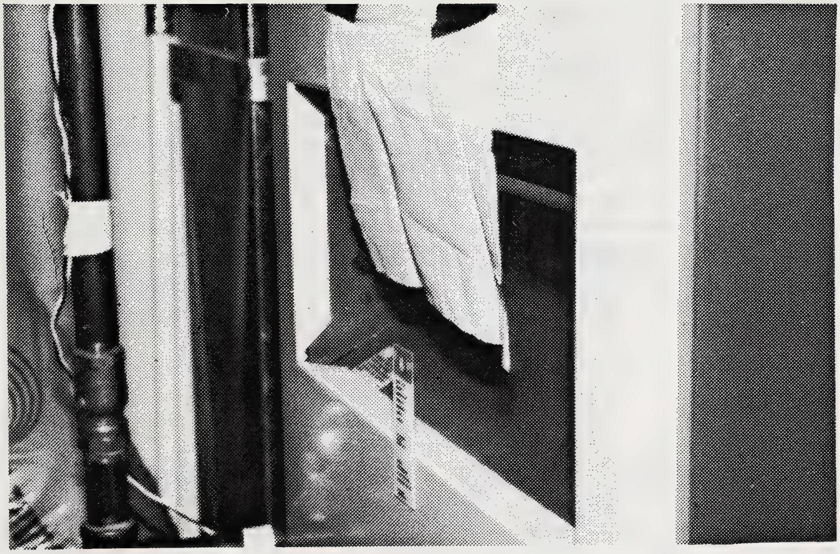


Photo 9.1

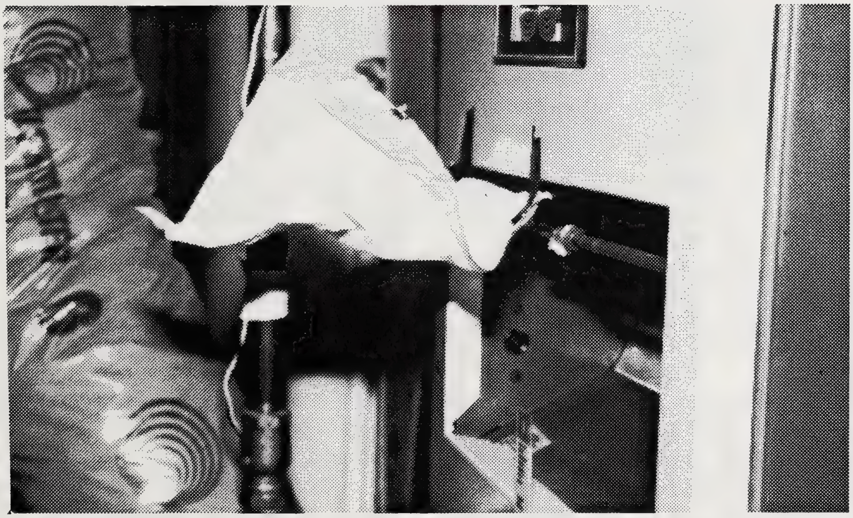


Photo 9.2

Backdraft Tests (Draft Inducer System)

9.4 Building Envelope Infiltration Rates

Air-flow data was used to determine the quantity of outside air entering the houses through the ventilation/makeup and combustion air ducts on a continuous basis. Daily and monthly averaged flows for combustion air-flow rates (Q_{CA}) and ventilation/makeup air-flow rates (Q_{MA}) from January through March are summarized in Table 9.2. The maximum flow rate when the furnace was on and the minimum flow rate when the furnace was off have also been included.

Table 9.2: COMBUSTION AND MAKEUP AIR-FLOW RATES (Q=L/s)

		Economizer	Induced Draft	
		Q_{CA}	Q_{MA}	Q_{CA}
JANUARY				
Furnace On	Max	24.0	N/A	18.6
Daily Average	Max	20.3	N/A	15.6
Monthly Average		14.0	N/A	12.3
Daily Average	Min	9.2	N/A	7.9
Furnace Off	Min	3.8	N/A	5.3
FEBRUARY				
Furnace On	Max	24.5	36.6	19.9
Daily Average	Max	22.9	22.6	19.2
Monthly Average		16.0	16.9	12.0
Daily Average	Min	13.0	3.0	11.2
Furnace Off	Min	6.0	1.9	8.0
MARCH				
Furnace On	Max	23.4	33.0	22.3
Daily Average	Max	21.2	23.5	18.0
Monthly Average		19.0	19.2	14.5
Daily Average	Min	13.9	13.9	12.0
Furnace Off	Min	3.2	5.5	8.8
APRIL				
Furnace On	Max	19.9	18.9	12.5
Daily Average	Max	14.6	15.1	9.9
Monthly Average		12.6	12.6	7.4
Daily Average	Min	10.6	11.0	6.7
Furnace Off	Min	5.1	7.1	6.5

The results of the air depressurization tests are presented in Table 9.3. The air change rate per hour with the houses depressurized to 50 Pa (ACH_{50}) is given along with the house volume, the equivalent leakage area (ELA), and the air-flow rate (Q) through the building envelope at 50, 10 and 5 Pa.

Table 9.3: AIR TEST RESULTS

House	Volume (m^3)	ACH_{50}	ELA (cm^2)	Q_{50} (L/s)	Q_{10} (L/s)	Q_5 (L/s)
Economizer	506	3.85	735	541	182	114
Induced Draft	493	3.86	658	529	164	98

Although typical leakage points such as windows and electrical outlets appeared to be relatively well sealed, substantial leakage occurred through the rim and header joist areas. The ELA for each of these houses is equivalent to approximately a 30 centimetre or 12 inch hole in the building envelope which accounts for significant air leakage. For example, the test results presented in Table 9.3 predict that, if the entire building envelope is depressurized to -5 Pa, 114 L/s would leak through the building envelope of the economizer house and 98 L/s across the building envelope of the induced draft house.

The ACH_{50} for these houses was somewhat higher than the average for new conventional houses built in Edmonton. A recent cross-Canada survey sponsored by Energy, Mines and Resources Canada (EMR) showed that the ACH_{50} of 10 new conventional houses in Edmonton averaged 3.00. The passive air change rate of four of these houses was also measured and averaged 0.24 ACH.

1. The Economizer System

There was no data available on the flow of air through the makeup air duct of the economizer system since this equipment was not operational until June 27. Natural infiltration and the combustion air duct provided all of the ventilation, makeup and combustion air requirements. As a result, air-flow through the combustion air duct could vary widely on a daily basis depending upon the heating cycle of the furnace and the demand of other exhaust appliances. This can be seen from the data presented in Table 9.2, and from Figure 9.1 which illustrates a stable day and from Figure 9.2 which shows large fluctuations.

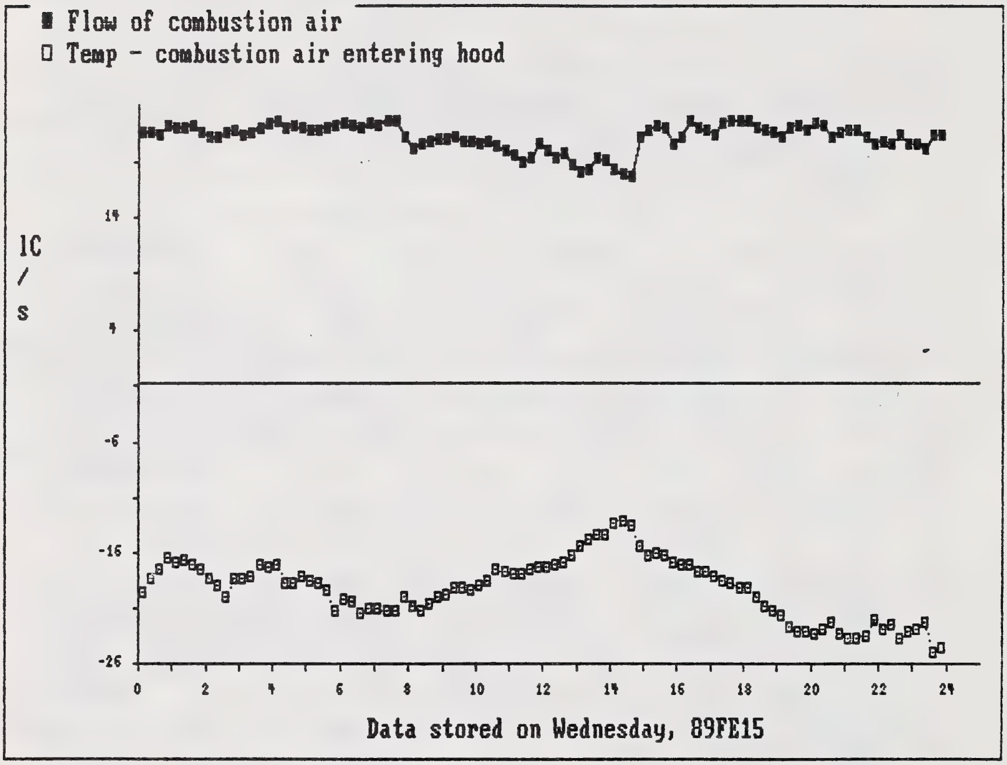


FIGURE 9.1 Stable Combustion Air Flows - Economizer System

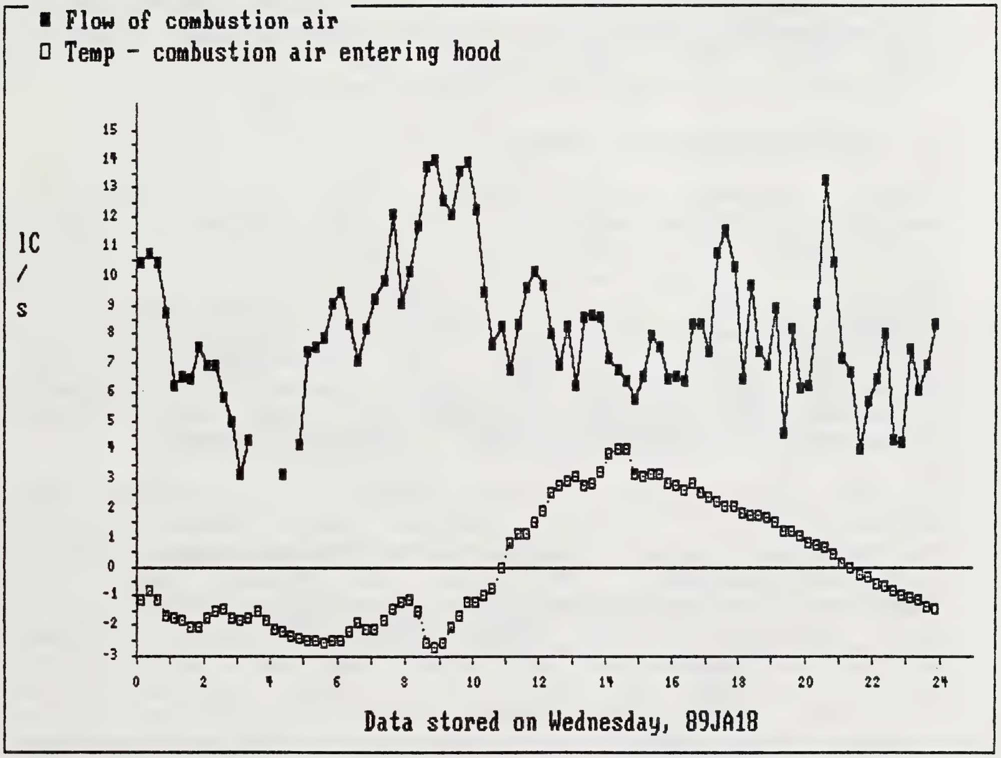


FIGURE 9.2 Variable Combustion Air Flows - Economizer System

From Table 9.2 it can also be seen that the greatest flows through the combustion air duct occurred in February and March when outdoor temperatures were lower and the fireplace was being used daily. An average daily flow of 19 L/s during March is equivalent to 0.14 air changes per hour (ACH) for this house. Based on the EMR passive air change test results, and the fact that the economizer makeup air line was not in use, the natural air change rate of the economizer house, which had an ACH_{50} of 3.85, would be approximately 0.2 to 0.3 ACH. This suggests that, in February and March, approximately one-half of the replacement air required by the economizer house was supplied through the combustion air duct while the other half was supplied by natural infiltration through the building envelope.

2. The Induced Draft System

This system incorporated both a combustion and ventilation/makeup air duct. The flow of makeup air showed wide variations since this duct was connected directly to the return air plenum and was affected by furnace operation. The combustion air duct, however, terminated near the furnace and water heater and was not directly connected to the air handling system. As a result, this flow was affected less by heating system operation and experienced smaller fluctuations throughout the day. This is illustrated in Figure 9.3.

As with the economizer house, Table 9.2 indicates that the highest flows in the induced draft house occurred in February and March. In March, the average daily temperature was approximately -9°C and the furnace was operating frequently. The average daily air-flow was 14.5 L/s through the combustion air duct and 19.2 L/s through the ventilation/makeup air duct resulting in a combined average daily air-flow of 33.7 L/s. This was equivalent to 0.25 ACH. Again, based on EMR's passive air change test results, the natural ventilation rate of this house would be approximately 0.3 ACH indicating that only 0.05 ACH were infiltrating through the building envelope.

This indication is reasonable since, when the furnace is operating, larger quantities of air are drawn in through the ventilation/makeup and combustion air ducts. As a result, the house is pressurized, the neutral pressure plane lowered and infiltration through the envelope is reduced.

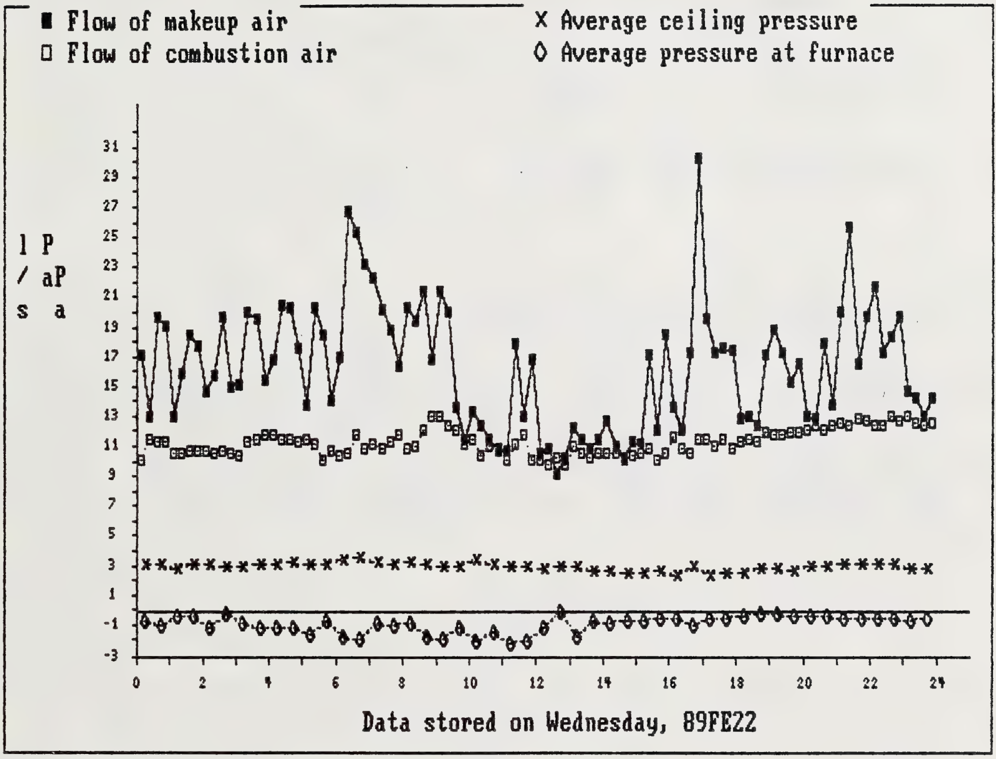


FIGURE 9.3 Typical Flows and Pressures - Induced Draft System

9.5 Air Quality Monitoring

As shown in Table 9.4, the formaldehyde levels in both houses were well below the limit of 0.1 parts per million (ppm) recommended by Health and Welfare Canada.

Table 9.4: FORMALDEHYDE TEST RESULTS

House	Room	Conc (ppm)
Economizer	Family	.049
	Bedroom	.053
Induced Draft	Family	.034
	Bedroom	.030

The higher levels detected in the economizer house can be attributed to the fact that the economizer system was not operational at the time of the test and the dampers controlling the amount of fresh air entering the return air plenum were taped shut. As a result, only natural leakage and the combustion air duct were available to supply ventilation, combustion and makeup air needs and the passive air change rate would be somewhat lower than the induced draft house.

It is important to note that, even with the economizer not operational, the formaldehyde levels recorded in this house were well within the limits set by Health and Welfare Canada. This suggests that provision for a separate ventilation air duct in this house may not be necessary to provide adequate indoor air quality.

During the winter months, the relative humidity in each of the houses was typically between 15% to 20%. As with the formaldehyde results, the low values are a direct result of the high infiltration rates due to natural leakage and continuous air-flow through the combustion and makeup air lines.

9.6 Air-flow Temperature Measurements

Air-flow temperature data was used to assist in evaluating the effect of the air entering the house through the combustion and ventilation/makeup ducts on indoor comfort levels and on energy consumption.

1. The Economizer System

With the economizer system not operational until June 27, the effect of air entering the return air plenum through the ventilation/makeup air duct could not be evaluated.

The air entering the house through the combustion air duct was tempered somewhat before it entered the basement. The degree of tempering depended on the temperature difference across the duct and the air-flow rate through the duct. On an average, however, when outdoor temperatures were below 0°C, the air entering the house at the combustion air bucket was approximately 8°C warmer than the outdoor temperature. After tempering, the lowest daily averaged combustion air temperature recorded entering the house was -14°C. This occurred when the average outdoor temperature was -24.4°C and the average combustion air-flow rate was 20.3 L/s, and is illustrated in Figure 9.4.

The homeowners expressed concern about the cold temperatures in the basement. They were not happy because this area was too cold for their children to play in comfortably during the colder winter days when they were usually indoors. With the economizer operational, much of this cold air will enter via the makeup air duct and go directly into the furnace rather than spilling onto the basement floor and help to alleviate this problem. The homeowners were also concerned about drafts caused by the continuous operation of the furnace fan. On June 27, the furnace fan problem was addressed by replacing the single speed furnace motor with a two-speed motor allowing the furnace fan to be operated on a lower speed.

2. The Induced Draft System

In this case, outdoor air was being drawn into the house through both a ventilation/makeup air and a combustion air duct. The degree of tempering of the ventilation/makeup air was less than the combustion air. When outdoor temperatures were below 0°C, the air entering the return air plenum through the ventilation/makeup air duct was approximately 4°C warmer than the outside air while air entering the house at the combustion air bucket was approximately 8°C warmer.

After tempering, the lowest average daily combustion air temperature recorded during the monitoring period was -16.7°C. For the day in which this occurred the average outdoor temperature was -32.7°C and the average combustion air-flow rate was 19.2 L/s. This is illustrated in Figure 9.5. These homeowners also expressed concern about the cold temperatures in the basement.

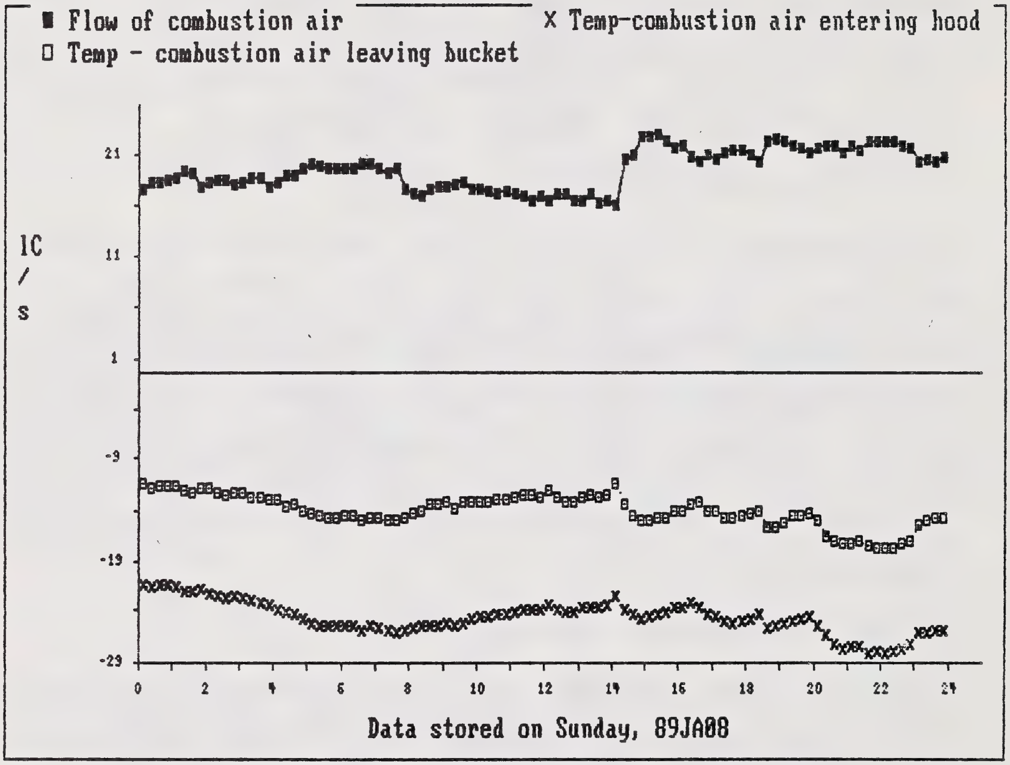


FIGURE 9.4 Minimum Combustion Air Temperature - Economizer System

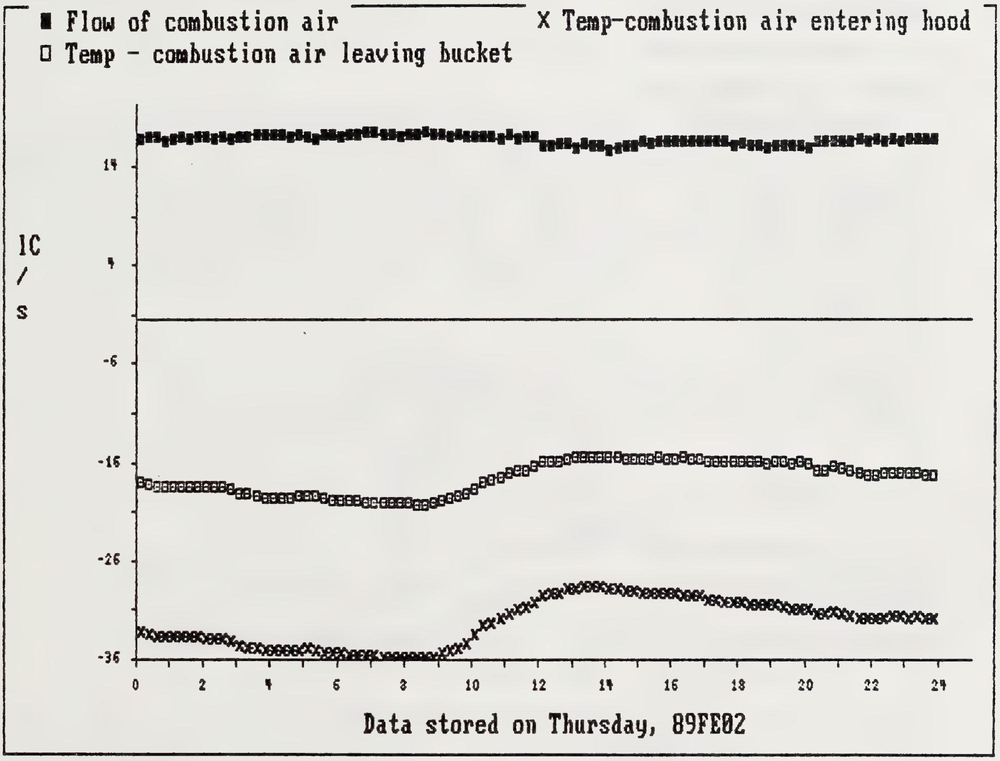


FIGURE 9.5 Minimum Combustion Air Temperatures - Induced Draft System

Introducing ventilation/makeup air into the return air plenum when outdoor temperatures were between 0°C and -20°C typically resulted in a drop of 7°C in the return air temperature. The largest drop recorded was 12°C which occurred when the outdoor temperature was -36°C. This is illustrated in Figure 9.6. If the homeowner decided to run the furnace fan continuously, return air temperatures reduced by this amount would result in uncomfortable drafts. The minimum temperature recommended by the Canadian Standards Association (CSA) for air supplied through floor diffusers is 17°C.

9.7 Energy Consumption

An annual space and domestic hot water gas projection was made for each of the houses using the actual gas consumption figures for a partial year and Northwestern Utilities Limited (NUL) projections for the remainder of the year. These figures, along with the NUL's average consumption figures for a 155 square meter house in Edmonton, are given in Table 9.5.

Table 9.5: ANNUAL GAS CONSUMPTION

House	Actual Gas	NUL Avg
	(GJ)	(GJ)
Economizer	210	195
Induced Draft	125	195

Both houses were close to the NUL average consumption for a similar sized Edmonton house. The large difference between the two houses can be explained by lifestyle. At the economizer house, the mother was home during the day caring for two preschool children and indoor temperatures were maintained at approximately 21°C. At the induced draft house, both parents were away at work during the day, both children were in school and the thermostat was often setback during the day and at night.

The electrical consumption of the economizer house was approximately twice as much as the induced draft house for a six month period from January to June. This can be accounted for partially by lifestyle differences but was due mainly to the continuous operation of the single speed furnace motor in the economizer house. This motor was replaced on June 27 with a two-speed motor. As discussed in Section 6.5, the two-speed motor will reduce the estimated

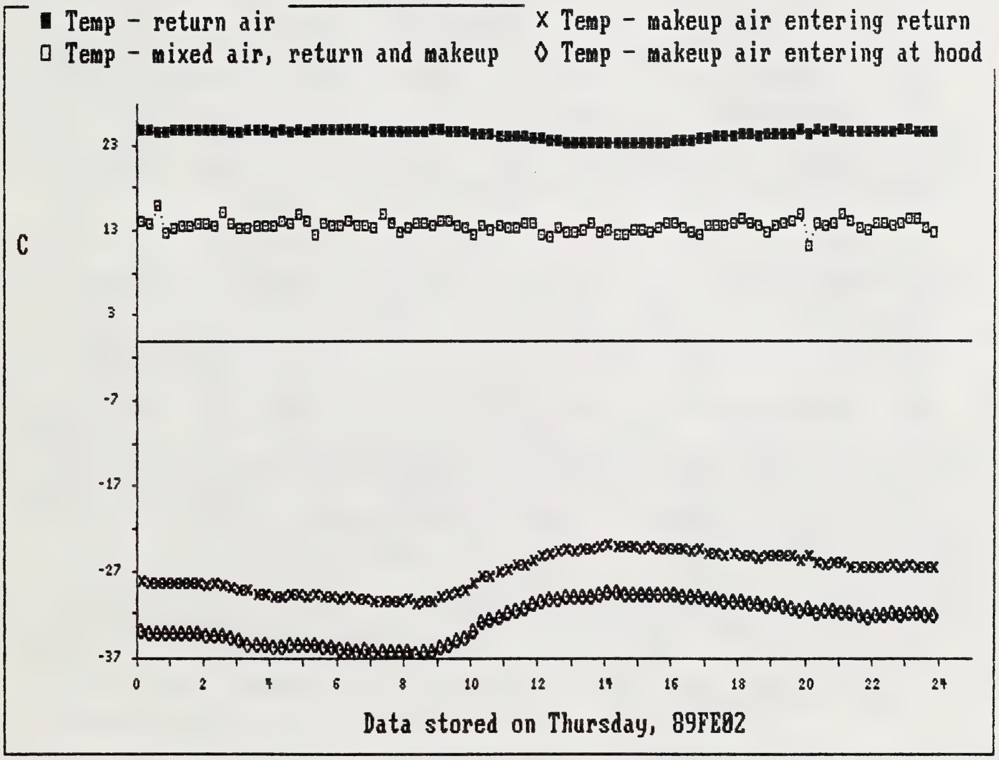


FIGURE 9.6 Mixed Air Temperature - Induced Draft System

cost of running the furnace fan continuously from $334 per year to $70 per year.

9.8 Industry Concerns Related to the Systems Tested

1. Alberta Labour, Building Standards Branch

Concerns regarding low combustion air temperatures entering the house have been expressed by Alberta Labour, Building Standards Branch, in the STANDATA 85-DI-017R2 issued in October 1988. The STANDATA details combustion air termination options that "will assist in the prevention of cold draughts on the floor within the general vicinity of the combustion air duct (in the past open ended combustion air ducts were often blocked off). It will also lessen the chance of water pipes (in the area below the combustion air duct) failing due to freezing temperatures."

In addition, to ensure that the smaller, more efficient furnaces with a low draw receive sufficient combustion air, the STANDATA goes on to state that, for gas fired appliances, "combustion air must terminate within 300 millimeters (mm) above and within 600 mm horizontally from the burner level of the appliance having the largest input." The combustion air terminations in each of the houses in this project were installed before this STANDATA was released and are currently installed with the outlet 300 mm above floor level and approximately 1.5 meters horizontally from the furnace. The combustion air duct shown in Photograph 6.17 is typical of these systems.

As shown by the monitoring data, significant quantities of cold air are continuously entering the house from these terminations. The problem can be solved by installing the electrically operated combustion air damper described in the latest STANDATA.

2. Canadian Standards Association

In January 1989, the Canadian Standards Association (CSA) published CSA Preliminary Standard F326.1-M989: **Residential Mechanical Ventilation Requirements.** Section 5.5, Supply Air Temperature - Thermal Comfort, states that ventilation systems "shall be designed and installed so that the temperature of ventilation air and its manner of introduction into each room are such as to avoid discomfort in the occupied zone." In Alberta, although floor diffusers may be preferable to deliver supply air for space heating, they are generally not designed to introduce air delivered by a continuously running furnace fan at room temperature or colder. As a result, the CSA has recommended that "unless air diffusers are especially designed and located, supply air temperatures in winter should not be less than 17°C with floor diffusers."

In the economizer house, where the furnace fan operates continuously, the furnace has been designed to eliminate drafts by sensing the temperature of the return air and tempering the supply air to the house when the return air drops below a set temperature. In the induced draft house, however, this furnace feature is not available and, if the homeowner wished to operate the furnace fan continuously in the winter, the monitoring data indicated that uncomfortable drafts would result.

In addition, Section 5.6, Minimum Supply Air Temperatures - Fuel-Fired Furnaces, states that "where ventilation air is introduced into the return air plenum of a fuel-fired furnace, it shall be tempered and/or mixed with return air so that the temperature of the circulating air in contact with the furnace's primary heat exchanger is not less than 12°C." Industry is concerned that excessive cooling of the heat exchanger can:

1. result in high thermal stresses when the burner comes on and can cause premature failure; and
2. result in condensation, increased corrosion, and reduced life expectancy.

In the induced draft house, with the makeup air duct operational, the lowest temperature measured for the return air mixed with makeup air was 12.5°C. This occurred when the outdoor temperature was -36°C and the flow of makeup air was 23 L/s. Even under these severe conditions, temperatures across the heat exchanger were above the CSA recommended value. The furnace in the economizer house is equipped with an aluminized heat exchanger and is capable of withstanding severe conditions.

9.9 Effectiveness Of Economizer "Free Cooling"

The system was first used for cooling towards the end of July. The homeowner indicated that experimentation was required in order to maximize the effectiveness of the cooling cycle. When indoor temperatures were high, the initial tendency was to start the timer before outdoor temperatures were low enough to cool the house. The homeowner also experimented with running the furnace fan at high and low speeds and determined that cooling was not effective with the furnace on low speed.

After the initial trial period, the homeowners were pleased with the operation of the cooling mode. They found that it was most effective when the timer was set for a full five hours commencing about eight o'clock in the evening and the furnace was switched to high speed and left until the next morning. A kitchen and bedroom window remained opened during periods of cooling. Table 9.6 displays typical temperatures recorded during the cooling cycle.

Table 9.6: TYPICAL FREE COOLING TEMPERATURES

Time	**Temp(°C)**	**Air Entering House**	**Return Air**	**Air Entering Room**
2000	Initial	24.0	26.0	26.0
0100	Final	18.5	24.0	21.5

10.0 CONCLUSIONS AND RECOMMENDATIONS

10.1 Introduction

This section presents the major conclusions and recommendations of this study. These respond to its main objectives which were to develop, field trial, and evaluate practical combustion air supply and ventilation systems for use in typical Alberta production housing, which also satisfy the present building code requirement to have a capability of providing 0.5 air changes per hour while ensuring safe conditions for combustion in gas-fired appliances.

As explained previously, eight potential solutions were presented for discussion and assessment by the project review committee. Of these, four were selected for further testing on the basis of their predicted performance and estimated costs. These four systems were the "Standata" method, the economizer, the draft inducer, and the sealed furnace room. The first three of these were monitored and evaluated in detail over a nine month period.

10.2 General Performance Characteristics

Tests of the four demonstrated systems indicated that the houses used in this demonstration did not develop negative pressures greater than 5.0 Pa with all bathroom and kitchen exhaust fans operating. Corresponding air change rates ranged from 0.8 to 1.1 air changes per hour, compared to the code requirement of 0.5 ACH. Since a negative pressure of 6.0 Pa is considered to be the level at which spillage begins to be a concern for natural draft appliances, it is concluded that all four demonstration systems satisfied the code requirements for ventilation rate and safe combustion conditions. These four systems were the "Standata" method, the economizer, the sealed furnace room and the draft inducer. However, as previously noted, the potential for backdrafting does exist if the clothes dryer is operated in conjunction with all the exhaust fans.

Tests of the ventilation systems in the four demonstration houses also showed that the installed washroom and kitchen exhaust fans operating together could provide more ventilation than the 0.5 ACH called for in the building code. In fact, this ventilation requirement was met in all four houses by using the kitchen exhaust fan alone. Conversely, the washroom exhaust fans could not achieve 0.5 ACH even in the case where three fans were operating together. The kitchen fans were found to be operating above their rated capacity, while the washroom fans were typically well below their rating.

The main reason for these discrepancies between actual and nominal air flows was the length, routing and type of ductwork installed on each fan. The kitchen fans had smooth-walled sheet metal ducts routed in a straight run up through the roof. In contrast, the washroom fans had corrugated flexible ducts with several bends. It should also be noted that the kitchen exhaust fans had a nominal capacity three times that of each washroom fan. The lesson to be learned from this is that ductwork for residential exhaust fans should be reasonably short and straight. If this is not feasible, the fan size should be increased to compensate for greater duct losses. Otherwise, exhaust capacity will be inadequate in the area served by a particular fan, although, if the house and mechanical system are similar to the ones in this study, total exhaust capability will still meet the building code requirements.

10.3 Comments On The Methods Tested

Given that all four systems met the basic requirements, the review committee recommended the continued use of the base case "Bucket Combustion Air, Ventilation to Return Air" (per Standata) approach since it best met the evaluation criteria listed in Section 5.2. It had the lowest construction cost, was the simplest to build, maintain and operate and was apparently the most reliable due to its simplicity and lack of moving parts or electrical controls.

However, it must be emphasized that this system relied heavily on building envelope leakage to supply make-up air. If the demonstration house had been more airtight, its natural draft appliances would have been subject to spillage and backdrafting, because the make-up air duct was not capable of supplying the code requirement of 0.5 ACH, let alone the total exhaust fan capacity at a pressure differential that would not cause backdrafting.

The potential for backdrafting in a tighter house could be reduced by increasing the size of the make-up air duct, but this could also result in excessive quantities of outside air being drawn in when the furnace blower is running. For this reason, this combustion air and make-up air system is not recommended for houses that are significantly more airtight than the ones tested in this study and where natural draft appliances are used.

If typical Alberta production houses, including those in the demonstration, had been more airtight, then one of the other potential solutions would have been recommended. Of the tested systems, the draft inducer appears to best meet the evaluation criteria under such conditions. As a single mechanical device (fan) with simple controls, it is easy to understand and install. Since it operates automatically and only during potential backdrafting conditions, it is not likely to wear out or need any attention from the homeowner. It is the least costly alternative to the base case.

However, it is not clear if the draft inducer is permitted by the gas code. Because it was not the primary recommended system arising from this study, efforts to get it accepted under the code were not carried through. It is recommended that this matter be followed-up through the CGA B149 Committee.

Another viable alternative is the use of induced draft appliances. They were considered during this study, but were not tested because other research has shown that they work and are generally resistant to backdrafting at negative pressure as high as 15 Pa, which is three times the maximum negative pressure measured in the four demonstration houses. Their higher seasonal efficiency can often result in fairly early payback of their higher initial costs, even with the low natural gas prices in Alberta.

The "sealed furnace room" as tested during this study, does not appear to be a viable approach due to the difficulty and cost of achieving a sealed room. The reliability and operability of the system are also questionable, since there is a fairly high probability of the furnace room door being inadvertently left open.

The economizer system is the only system examined during the course of this study which can truly provide pressure balanced make-up air and combustion air under all anticipated conditions. However, as previously discussed, typical Alberta production housing does not require this level of sophistication in ventilation control. This system is also costly to install and operate, and may not be reliable because of the sophisticated electronic controls and damper actuator.

Based on this discussion, the review committee recommended that the "Bucket Combustion Air, Ventilation to Return Air" system, with bathroom and kitchen exhaust fans, continue to be used for typical Alberta production housing. Special provisions must be made, however, in cases where make-up air or exhaust ducts are longer or have more bends than normal. Furthermore, if additional efforts are made to air-seal houses, such as an air barrier spanning the wall to rim-joist to basement connections, then this system is likely to cause backdrafting of natural draft appliances. To overcome this problem, the use of a draft inducer, or induced draft appliances, is recommended. The draft inducer has a low initial cost, negligible operating costs and requires no interaction from the homeowner. The draft inducer would require approval by the gas protection authorities before it could be used however.

10.4 Comments On The Findings From Continuous Monitoring

The objective of the computerized monitoring project was to determine the reliability, workability, cost of operation and resistance to furnace backdrafting of three ventilation and combustion air systems developed and installed under the initial project. The three systems were:

1. the bucket combustion air, ventilation to return air duct (as per STANDATA 85-DI-017R);
2. the above STANDATA with the addition of a draft inducer fan in the common flue pipe serving the gas fired furnace and water heater; and
3. the economizer (mixing tee) system with separate a combustion air duct.

The building envelopes of the two conventionally built, new houses in which these systems were installed were sufficiently leaky that, when combined with the STANDATA system, there was adequate makeup air to prevent the negative pressures that can cause backdrafting. In addition, the low measured formaldehyde levels indicated that pollutant sources were being controlled while the low measured humidity levels indicated that these houses were actually being overventilated.

Since the induced draft fan system was not called upon to reverse a backdrafting flue and the economizer system was not operational during the heating system, conclusions about the reliability of these systems cannot be made. From the backdrafting tests that were carried out, however, it is known that the systems are capable of preventing backdrafting within the limits specified by the manufacturer.

The workability of the systems can only be evaluated with regards to the economizer system since the other two systems do not require any homeowner interaction. With the economizer system, the homeowners only had the opportunity to evaluate the summer cooling mode of operation. After some experimentation, they were able to use the system to effectively cool the house and were pleased with its operation.

The cost of operation of the three systems was only an issue with the economizer system. The STANDATA system is required by code and was, therefore, the base case. The induced draft fan operates only if backdrafting occurs and, since it did not occur, there was no operating cost involved. The major cost in operating the economizer system is the cost of electricity to run the furnace fan continuously. In the system evaluated for this project, it was necessary to replace the single speed fan motor with a two-speed motor in order to reduce drafts and noise. This change reduced the estimated operation cost from $334 to $70 per year. Since the system was not operational, it was not possible to do any additional analysis.

If these homes are considered typical of newly constructed, conventional homes, then the monitoring results substantiate the previous recommendation that the STANDATA system is more than adequate as a ventilation and combustion air system. In stating that the system is more than adequate, it is noted that a continuous flow of outside air in the combustion air duct resulted in undesirable cold conditions in the basement. Accordingly, it is also recommended that a device be installed to control the continuous flow of outside air entering the house through the combustion air line. The device specified as an option in the latest STANDATA is an electrically operated combustion air damper. This recommendation should result in increased comfort and reduced heating bills.

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APPENDIX A

LITERATURE REVIEW

This section summarizes a review of published information related to combustion venting for residential housing.

A.1 **CHIMNEY VENTING PERFORMANCE STUDY - 1986**; Timusk, Selby and Seskus, University of Toronto, 1986

Purpose: This study examines the relationship between house depressurization and chimney venting failure.

Scope: In this study the following were to be established:

1. House pressures at which naturally aspirating gas furnaces and gas domestic water heaters (DWH) in conjunction with their chimneys can (a) establish venting and (b) at which established venting can be reversed.
2. The capacity of installed fans, including fireplaces, to exhaust air over a range of negative pressures.
3. House envelope tightness characteristics according to Canadian General Standards Board (CGSB) testing specification CAN2-149.10-M83.

Methodology: Forty houses in the Toronto area were tested to determine their pressure vs. chimney venting characteristics. A door fan was used to depressurize the house. Multiple tests were run on each house with different combinations of air exhausting equipment in use. The difference between the multiple tests would represent various pieces of exhausting equipment in use. The difference between the multiple tests would be a measure of the exhaust rates of the installed air using equipment. This testing also included the measurement of the furnace room depressurization created by each air exhauster in the house.

Major Conclusion:

Results showed that the probability of venting failure to occur even in worst case conditions is very small.

A.2 **THE PERFORMANCE TESTING OF FOUR RESIDENTIAL COMBUSTION AIR SUPPLY SYSTEMS**; Michael Tremayne, The Consumers Gas Company Ltd., Toronto 1987

Purpose: The purpose of this study was to evaluate the performance of combustion air supply systems under various pressure differences.

Scope: This study is a part of a larger study undertaken to gain a better understanding of house air supply and demand and to gain a better understanding on how prone the housing stock might be to venting failure. The larger study has two aspects to it. One part consisted of studying depressurization and is the study outlined in Appendix A.1 above and the other part is this one which studies combustion air supply systems.

Methodology: Four combustion air supply systems were subject to various levels of depressurization and their pressure vs. flowrate characteristics were studied.

Major Conclusion:

Draft inducers proved to be the most attractive option and the other systems varied in effectiveness.

A.3 **IMPACT OF RESIDENTIAL AIR SUPPLY AND DEMAND ON VENTING OF GAS APPLIANCES**; Timusk, Rinella and Kohl, The University of Toronto.

Purpose & Scope: This paper is a brief overview of A.1 and A.2 above.

A.4 **RESIDENTIAL COMBUSTION VENTING FAILURE - A SYSTEMS APPROACH SUMMARY REPORT**; Scanada Sheltair Consortium, 1987

Purpose: The purpose of this report was to summarize the state-of-the-art in the study of venting failure and the factors that affect it.

Scope: The scope of this summary involved a survey of approximately 1000 houses in Canada to estimate the extent of venting failure, to refine existing field detection/diagnosis procedures, to study pollutants caused by venting failure, review remedial measures, to draft new strategies and to improve computer modeling of furnace/flue/house systems.

Methodology: This summary reports on the state-of-the-art in the study of venting failure and develops new tools to aid in its understanding and modeling.

Major Conclusion:

The results indicate that a significant portion of the housing stock has potential for venting failure to occur regularly but such failures are not necessarily life-or health-threatening.

A.5 **HEATING AND VENTILATION OF MODERN HOUSING**; A. Newton, Alberta Municipal Affairs, 1987.

Purpose: This paper examined the inter-relationship between the building envelope in airtight housing and the heating and ventilating system.

Scope: This paper examined the following:

- backdrafting of combustion appliances
- outside air change rates required to prevent condensation on various glazing at various outdoor conditions
- indoor air quality
- forced and natural ventilation rates

Methodology: The study employed a literature search to collect and review information and engineering analysis to examine backdrafting, ventilation and payback of various energy conservation measures.

Major Conclusions:

Standard houses derive a significant portion of their ventilation from the uncontrolled infiltration of outside air. Retrofitting these houses to airtight standards without regard to the provision of proper amounts of ventilation air can result in elevated indoor pollution levels and backdrafting. If existing building envelopes are retrofitted, gas-fired appliances should be provided with induced draft fans and fireplaces should be uncoupled. New buildings with air tight envelopes should be equipped with forced draft or otherwise uncoupled appliances. Heat recovery ventilators may become economically viable with higher minimum ventilation rates.

APPENDIX B

CALCULATIONS

B.1 Natural gas Composition for Edmonton Area (Source - Northwestern Utilities Laboratory Ph: 420-7211)

Constituent	Volume %
CH_4 (methane)	95.06
C_2H_6 (ethane)	1.76
C_3H_8 (propane)	0.07
CO_2 (carbon dioxide)	0.84
N_2 (nitrogen)	2.31

B.2 Combustion Reactions

$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$

$C_2H_6 + 3.5O_2 \longrightarrow 2CO_2 + 3H_2O$

$C_3H_8 + 5O_2 = 3CO_2 + 4H_2O$

B.3 Air Requirements for Stoichiometric Combustion (Source - ASHRAE 1985 Fundamentals - Chapter 15, Table #1)

for one cubic foot of Edmonton area natural gas:
0.9506 cubic ft. CH_4 requires 9.10 cubic ft. air
0.0172 cubic ft. C_2H_6 requires 0.29 cubic ft. air
0.0007 cubic ft. C_3H_8 requires 0.017 cubic ft. air

Therefore 9.41 cubic feet of air is required for the stoichiometric combustion of one cubic foot of Edmonton area natural gas.

B.4 Heating Value of Edmonton Area Natural Gas (Source - ASHRAE 1985 Fundamentals - Chapter 15, Table #2)

for one cubic foot of natural gas
Methane (CH_4)
95.06 vol % = 95.06×10^{-2} cubic feet
$95.06(10^{-2})\text{ft}^3 \times 4.48 \times 10^{-2}\text{lb/ft}^3 \times 23{,}875$ BTU/lb
= 1016.76 BTU

Ethane (C_2H_6)
1.76 vol % = 1.76×10^{-2} cubic feet
$1.76 \times 10^{-2}\text{ft}^3 \times 7.83 \times 10^{-2}\text{lb/ft}^3 \times 22{,}323$ BTU/lb
= 30.76 BTU

Propane (C_3H_8)
0.07 vol % = 7×10^{-4} cubic feet
$0.07 \times 10^{-2}\text{ft}^3 \times 12.6 \times 10^{-2}\text{ lb/ft}^3 \times 21{,}669$ BTU/lb
= 1.91 BTU
Total = 1049.43 BTU/ft^3 Edmonton area natural gas

B.5 Ventilation Air Determination

Ventilation Air Requirements for an average Alberta house:

Assume
- an average 1500 square foot house with basement and first floor
- an 8 foot high inside wall height
- continuous mechanical ventilation air equipment operation

therefore 1,500 sq. ft x 2 fl. x 8 ft = 24,000 cubic ft.
1/2 ACH x 24,000 cubic ft = 12,000 ft^3/hr
12,000 ft^3/hr x hr/60min = 200 CFM

B.6 Cost of 1/2 ACH Ventilation Air
(continuous operation)

Working equation -->
Cost = 1.08 x CFM x $(T_i - T_o)/e$ x Hours/100,000 x R

where
T_i = inside design temperature
T_o = average outside temperature during heating season
e = efficiency of furnace (seasonal)
R = dollar cost of 1 therm of natural gas energy
Hours = duration of heating season (hours)

therefore Cost = 1.08 x 200 x 47/0.6 x 5,110/100,000 x .3
= $ 259 per year

APPENDIX C

CODE REFERENCES

SUBSECTION 9.33.3. MECHANICAL VENTILATION

9.33.3.1. ***Dwelling units*** shall have a mechanical ventilation system capable of providing at least one half an air change per hour during the heating season, based on the interior finished volume of the ***dwelling unit***. The system shall be controlled either manually by a switch or automatically. (See Appendix A.)

Mechanical ventilation required

9.33.3.2. Where rooms or spaces in ***dwelling units*** are provided with mechanical ventilation systems in lieu of natural ventilation as required in Article 9.33.1.5., the systems shall be capable of providing at least 1 air change per hour where summer cooling is not provided or at least half an air change per hour where summer cooling is provided.

9.33.3.3. Mechanical ventilation systems for ***dwelling units*** shall include provision for introduction of fresh make-up air from the exterior.

Make-up air

9.33.3.4. Mechanical ventilation systems in combination with central heating or cooling systems shall conform with Part 6.

9.33.3.5. ***Exhaust ducts*** shall discharge directly to the outdoors. Where the ***exhaust duct*** passes through or is adjacent to unheated space, the duct shall be insulated to prevent moisture condensation in the duct.

Exhaust discharge

9.33.3.6. Ventilation equipment shall be accessible for inspection, maintenance, repair and cleaning. Kitchen ***exhaust ducts*** shall be designed and installed so that the entire duct can be cleaned where the duct is not equipped with a filter at the intake end.

Access to ventilation equipment

9.33.3.7. Outdoor air intake and exhaust outlets shall be shielded from weather and insects. Screening shall be of rust-proof material.

Air intake shield

9.33.3.8. Ventilating ducts shall conform to the requirements of Part 6 for ***supply ducts***, except ***exhaust ducts*** that serve only a bathroom or water-closet room may be of ***combustible*** material provided the duct is reasonably air tight and constructed of a material impervious to water.

★ **9.33.3.9.** An enclosed ***exit*** stairway that serves more than one ***storey*** shall not be heated, ventilated or air-conditioned using an air system that serves other parts of the ***building***.

★ **9.33.3.10.(1)** In a ***residential occupancy*** all clothes dryer vents shall be ducted to the outside, and if clothes dryers are collectively vented, a sheet metal duct shall be provided and a continuously operating fan positioned upstream from all outlets to positively exhaust all moisture and lint.

★ **9.33.3.10.(2)** A screen is not permitted on a clothes dryer vent.

9.33.3.10.(3) Suitable access doors shall be installed in a clothes dryer vent for cleaning purposes.

★ **9.33.3.10.(4)** A clothes dryer vent shall not be connected to any other exhaust system, ***gas vent*** or ***chimney***.

A-9.33.3.1. Mechanical Ventilation. The tendency toward achieving higher levels of airtightness in housing and other concerns over energy conservation indicate that natural ventilation is not sufficient to ensure acceptable air quality during the winter heating season. The mechanical system required by this Article is, therefore, independent of natural sources, including windows and air infiltration.

This Article does not require that a centralized ventilation system be provided with duct work leading to all parts of the dwelling unit. The requirement may be satisfied by means of exhaust fans located in kitchen or bathroom areas where a fresh air inlet is provided at a location remote from the exhaust outlet. A ventilation system operating in conjunction with a central heating or cooling system comes under the jurisdiction of Part 6.

★ **6.2.3.12.(1)** A sufficient quantity of make-up air shall be provided for a ventilation system that exhausts air to the outdoors so as not to affect adversely ***appliances*** in the ***building*** or the exhaust system. (See Appendix A.)

Air openings

6.2.3.12.(2) Supply, return and exhaust air openings in rooms or spaces in ***buildings*** when located less than 2 m above the floor shall be protected by grilles having openings of a size that will not allow the passage of a 15 mm diam sphere.

6.2.3.12.(3) ***Combustible*** grilles, diffusers and other devices for supply-, return- and exhaust-air openings in rooms shall conform to the ***flame-spread rating*** and smoke developed classification requirements for the interior finish of the surface on which they are installed.

6.2.3.12.(4) Outdoor air intakes and exhaust outlets at the ***building*** exterior shall be designed or located so that the air entering the ***building*** system will not contain more contaminants than the normal exterior air of the locality in which the ***building*** is situated.

6.2.3.12.(5) Exterior openings for outdoor air intakes and exhaust outlets shall be shielded from the entry of snow and rain and shall be fitted with corrosion-resistant screens of mesh not larger than 15 mm, except where climatic conditions may require larger openings.

6.2.3.12.(6) Screens required in Sentence (5) shall be accessible for maintenance.

★ **6.2.3.12.(7)** During winter operation make-up air that is introduced into a ***building*** shall be preheated.

Air filters

6.2.3.13.(1) Air filters for air duct systems shall conform to the requirements for Class 2 air filter units as described in CAN4-S111, "Standard Method of Fire Tests For Air Filter Units."

Air washers

6.2.3.13.(2) The filter and water evaporation medium of every air washer and evaporative cooling section enclosed within a ***building*** shall be made of ***noncombustible*** material.

Sumps

6.2.3.13.(3) Sumps for air washer and evaporative cooling sections shall be constructed and installed so that they can be flushed and drained.

Evaporative cooling equipment

6.2.3.13.(4) Evaporative cooling sections or towers of ***combustible*** material located on or outside ***buildings*** shall have a clearance of at least 12 m from sources of ignition such as ***chimneys*** or incinerators when the tower exterior construction is ***noncombustible,*** and a clearance of at least 30 m when the tower exterior construction is ***combustible.***

6.2.3.13.(5) Evaporative cooling sections or towers the main structure of which exceeds a volume of 55 m^3 shall comply with the requirements of NFPA 214, "Water-Cooling Towers."

Electrostatic filters

6.2.3.13.(6) Electrostatic-type filters when used shall be installed to ensure that the electric circuit is automatically de-energized when access doors are opened.

6.2.3.13.(7) Facilities for flushing and drainage shall be provided where filters are designed to be washed in place.

Odour removal equipment

6.2.3.13.(8) When odour removal equipment of the adsorption type is used it shall be
- (a) installed to provide access so that adsorption material can be reactivated or renewed, and
- (b) protected from dust accumulation by air filters installed on the inlet side.

Fans

6.2.3.14.(1) Fans for heating, ventilating and air-conditioning systems shall be located and installed so that their operation
- (a) does not adversely affect the draft required for proper operation of fuel-fired ***appliances***, and

DIRECTOR'S
INTERPRETATIONS **STANDATA**

JANUARY 1986 85-DI-017
Page 1 of 2

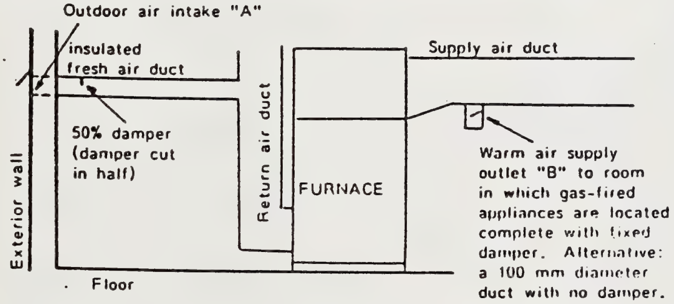
COMBUSTION AIR FOR DWELLING UNITS

This bulletin has been developed jointly by the Building Standards Branch and the Plumbing and Gas Safety Services Branch to clarify the requirements for combustion air for gas fired appliances that are installed in dwelling units.

The following two methods are acceptable to both branches and satisfy codes and regulations with regard to installation of gas fired furnaces and hot water heaters in dwelling units. (Other methods that give equivalent performance may be accepted by the two branches.)

METHOD 1

(Prior to using this method in R-2000 or similar homes designed for low infiltration, contact your local Building Inspector).


Outdoor air intake "A"
insulated fresh air duct
50% damper (damper cut in half)
Exterior wall
Return air duct
FURNACE
Supply air duct
Warm air supply outlet "B" to room in which gas-fired appliances are located complete with fixed damper. Alternative: a 100 mm diameter duct with no damper.
Floor

The furnace fan should be run continuously (a two speed fan would be advisable) so that combustion air will always be available for the hot water heater.

The warm air supply outlet supplying the space in which the gas fired appliances are located must be provided with a fixed damper set at the required air volume for the appliances, however a 100 mm diameter duct with no damper is also acceptable.

Normally 10 volumes of combustion air are required for each unit volume of natural gas. In addition to combustion air an equal volume of dilution air is required unless the venting system produces the exact draft necessary for each appliance. For the majority of installations 20 volumes of combustion and dilution air need to be supplied to the dwelling unit for each unit volume of natural gas used by the appliances and this air must be brought into the space containing the appliance.

The sizing of the combined combustion air and fresh air duct and the air intake will depend on the quantity of air required for combustion air and for all other air requirements in the building.

ISSUE OF THIS INTERPRETATION IS AUTHORIZED UNDER SENTENCE 1.5.4.2.(15) OF THE ALBERTA BUILDING CODE 1985 BY THE DIRECTOR OF BUILDING STANDARDS

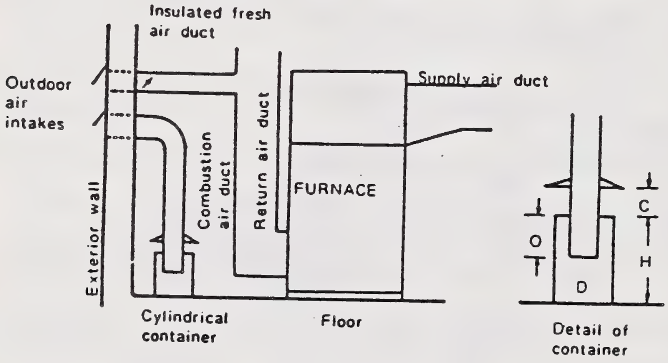
D. O. MONSEN, M.R.A.I.C.

Alberta

The following table is for guidance only. It assumes that the combined combustion air and fresh air duct is short and has not more than 2 elbows or other restrictions to air flow (not including the 50% damper).

Appliances	Combined Input kW	Minimum size of Combined Combustion Air and Fresh Air Duct
One Furnace & One Hot Water Heater	up to 30	125 mm diameter
	over 30, not more than 45	150 mm diameter
	over 45, not more than 60	175 mm diameter
Two Furnaces & One Hot Water Heater	up to 60	125 mm diameter for each furnace
	over 60, not more than 90	150 mm diameter for each furnace

METHOD 2



The cylindrical combustion air container must be bottomless so that it can be lifted up to remove debris that may fall in. The container diameter D must be at least 75 mm larger than the diameter of the combustion air duct. The combustion air duct must not extend more than 150 mm into the container (dimension X). The height of the container H must be at least 300 mm. The conical shroud shall be fastened to the combustion air duct, shall have an outer diameter at least 75 mm larger than the container diameter D and the clearance C between the bottom of the shroud and the top of the container shall be not less than 100 mm and not more than 150 mm.

The combustion air duct must be sized to have an area of at least 450 mm^2/kW based on the input rating of all appliances that it will serve.

Warning: The above information about supply of combustion air for gas fired appliances does not take into account other appliances and spaces in the dwelling unit that must be supplied with either make-up or combustion air (examples include attached garages, fireplaces, wood stoves, clothes dryers kitchen, washroom and other exhaust systems.)

NOTE: 15 kW = 50,000 Btu/h (approx.)

DIRECTOR'S
INTERPRETATIONS STANDATA

OCTOBER 1987 85-DI-017R
Page 1 of 2

COMBUSTION AIR FOR DWELLING UNITS

This bulletin has been developed jointly by the Building Standards Branch and the Plumbing and Gas Safety Services Branch to clarify the requirements for combustion air for gas and solid fuel (wood/coal) burning appliances that are installed within dwelling units.

The information provided relates only to the quantities and methods of providing combustion air for appliances and does not cover the quantities of air removed by mechanical ventilation systems that are also required for all dwelling units.

Other methods may be accepted - contact your local gas (for gas fired appliances) or building (for solid fuel fire appliances) inspector for further information.

Furnaces and Boilers

Appliance (fuel burned)	Area of Combustion Air Duct (based on input of all appliances in space)
Gas	CAN/CGA B149.1 CAN/CGA B149.2
Solid Fuel (example: wood and coal)	3300 mm^2/kW

All combustion air ducts should be as straight and short as possible. Normally no more than two elbows may be used unless the duct size is increased.

The cylindrical combustion air container must be bottomless so that it can be lifted up to remove debris that may fall in. The container diameter "D" must be at least 75 mm larger than the diameter of the combustion air duct. The combustion air duct must not extend more than 150 mm into the container (dimension "O"). The height of the container "H" must be at least 300 mm. The conical shroud shall be fastened to the combustion air duct, shall have an outer diameter at least 75 mm larger than the container diameter "D" and the clearance "C" between the bottom of the shroud and the top of the container shall be not less than 100 mm and not more than 150 mm. (see sketches on page #2)

Warning: The above information about supply of combustion air for gas and solid fuel fired appliances does not take into account other appliances and spaces in the dwelling unit that must be supplied with either make-up or combustion air (examples include attached garages, clothes dryers, kitchen, washroom and other exhaust systems).

NOTE: 15 kW = 50,000 Btu/h (approx.)

ISSUE OF THIS INTERPRETATION IS AUTHORIZED UNDER SENTENCE 1.5.4.2.(15) OF THE ALBERTA BUILDING CODE 1985 BY THE DIRECTOR OF BUILDING STANDARDS

D. O. MONSEN, M.R.A.I.C.

Alberta

Outdoor Air Intakes

One for mechanical ventilation

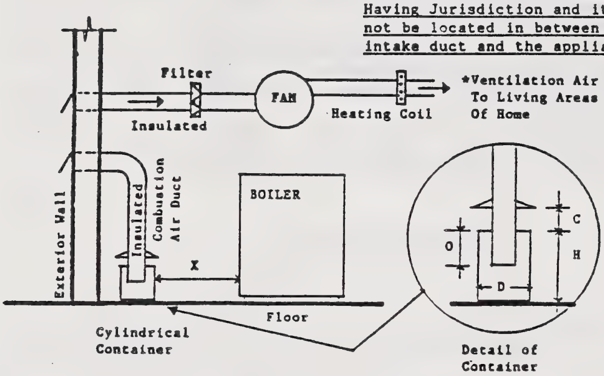
One for combustion air

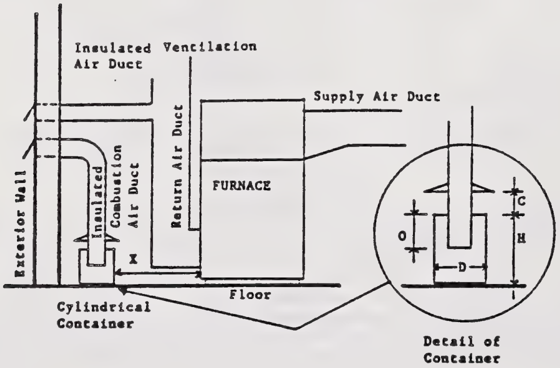
C = between 100 and 150 mm
D = diameter of container
H = 300 mm
O = 150 mm

x = combustion air must be within 600mm of appliance with largest input.

* An air to air heat exchanger may be used for ventilation in lieu of fan/coil system shown.

WARNING: water pipes shall not be located within 3m of the combustion air intake duct unless accepted by the Authority Having Jurisdiction and it shall not be located in between the intake duct and the appliance.





Fireplaces, Stoves, Space Heaters and Ranges Burning Solid Fuel

Combustion air must be supplied by one of the two following methods:

1. Directly to the fire chamber (for factory built appliances the units must be tested and listed with this feature and complete installation instructions are required). For fireplaces, glass doors are normally required in order for this method to be workable.

2. Directly to the room in which the appliance is located. This can be accomplished by installing a duct leading directly from outside the building into the room where the appliance is located. The duct should be as straight and short as possible and should have the same cross sectional area as the inside of the stovepipe (or chimney) that serves the appliance. A dampering mechanism is also required so that the duct may be closed when the appliance is not in operation.

DIRECTOR'S INTERPRETATIONS STANDATA

OCTOBER 1988 85-DI-017R2
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COMBUSTION AIR FOR DWELLING UNITS

This bulletin has been developed jointly by the Building Standards Branch and the Plumbing and Gas Safety Services Branch to clarify the requirements for combustion air for gas, oil and solid fuel (wood/coal) burning appliances that are installed within dwelling units.

The information provided relates only to the quantities and methods of providing combustion air for appliances and does not cover the quantities of air removed by mechanical ventilation systems that are also required to be provided for all dwelling units.

Other methods may be accepted - contact your local gas (for gas fired appliances) or building (for oil and solid fuel fired appliances) inspector for further information.

Fireplaces, Stoves, Space Heaters and Ranges Burning Solid Fuel

Combustion air must be supplied by one of the two following methods:

1. Directly to the fire chamber (for factory built appliances the units must be tested and listed with this feature and complete installation instructions are required). For fireplaces, glass doors are normally required in order for this method to be workable.
2. Directly to the room in which the appliance is located. This can be accomplished by installing a duct leading directly from outside the building into the room where the appliance is located. The duct should be as straight and short as possible and should have the same cross sectional area as the inside of the stovepipe (or chimney) that serves the appliance. A dampering mechanism is also required so that the duct may be closed when the appliance is not in operation.

Furnaces and Boilers

Appliance (fuel burned)	Area of Combustion Air Duct (based on input of all appliances in space)
Gas	CAN/CGA B149.1 CAN/CGA B149.2
Oil	CSA B139
Solid Fuel (example: wood and coal)	3300 mm^2/kW

All combustion air ducts should be as straight and short as possible. Normally no more than two elbows may be used unless the duct size is increased.

ISSUE OF THIS INTERPRETATION IS AUTHORIZED UNDER SENTENCE 1.5.4.2.(15) OF THE ALBERTA BUILDING CODE 1985 BY THE DIRECTOR OF BUILDING STANDARDS

D. O. MONSEN, M.R.A.I.C.

Alberta

Building Standards Branch
705 — 10808 - 99 Avenue, Edmonton, Alberta, Canada. T5K 0G2

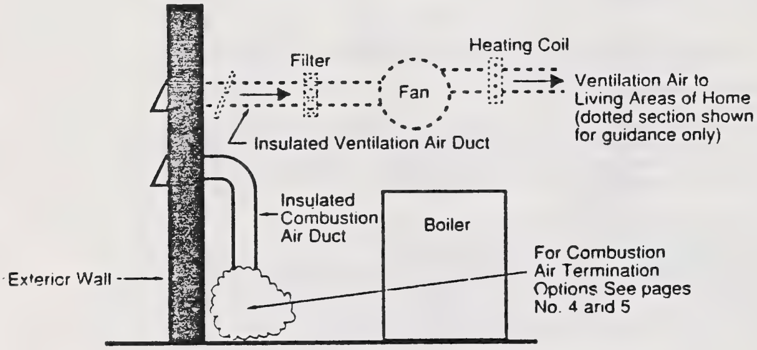
LABOUR
General Safety Services Division

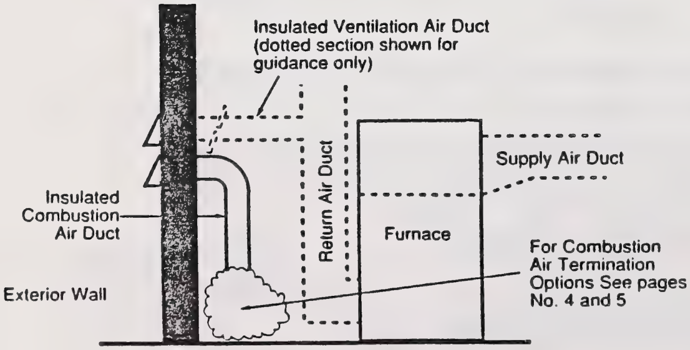
OIL AND SOLID FUEL FIRED FURNACES AND BOILERS

NOTE

The combustion air termination options shown on pages #4 and 5 will assist in the prevention of cold draughts on the floor within the general vicinity of the combustion air duct (in the past open ended combustion air ducts were often blocked off). It will also lessen the chance of water pipes (in the area below the combustion air duct) failing due to freezing temperatures (at least one option must be used).

* An air to air heat exchanger may be used for ventilation in lieu of fan/coil system shown.


Heating Coil
Filter
Fan
Ventilation Air to Living Areas of Home (dotted section shown for guidance only)
Insulated Ventilation Air Duct
Insulated Combustion Air Duct
Boiler
For Combustion Air Termination Options See pages No. 4 and 5
Exterior Wall


Insulated Ventilation Air Duct (dotted section shown for guidance only)
Return Air Duct
Supply Air Duct
Insulated Combustion Air Duct
Furnace
For Combustion Air Termination Options See pages No. 4 and 5
Exterior Wall

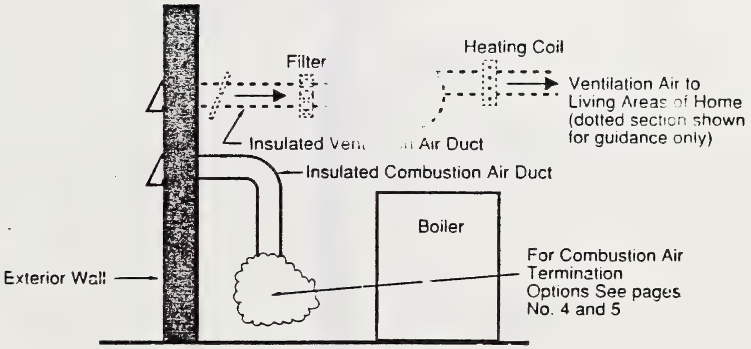
GAS FIRED APPLIANCES

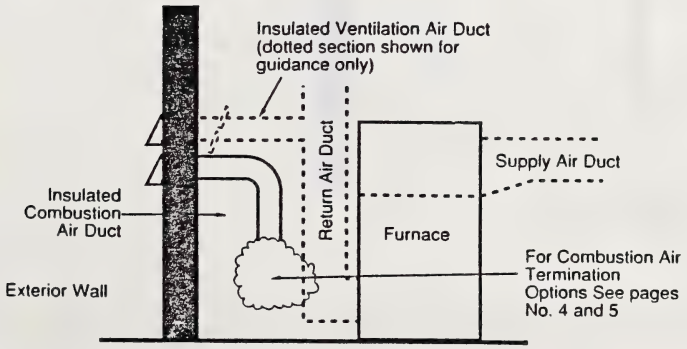
NOTE

The combustion air termination options shown on pages #4 and 5 will assist in the prevention of cold draughts on the floor within the general vicinity of the combustion air duct (in the past open ended combustion air ducts were often blocked off). It will also lessen the chance of water pipes (in the area below the combustion air duct) failing due to freezing temperatures (at least one option must be used).

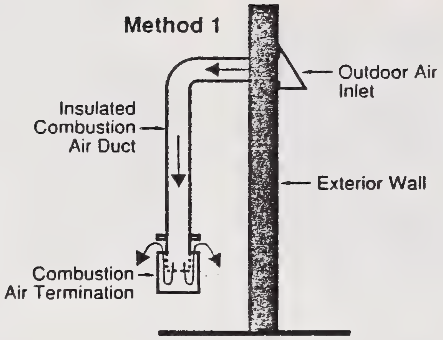
Combustion air must terminate within 300 mm above and within 600 mm horizontally from the burner level of the appliance having the largest input.

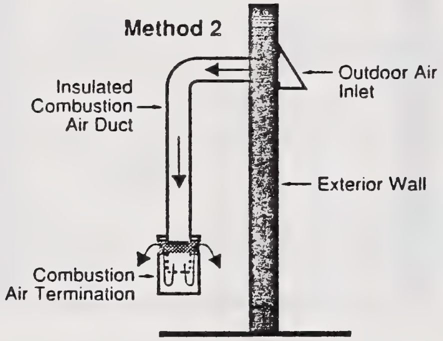
* An air to air heat exchanger may be used for ventilation in lieu of fan/coil system shown.

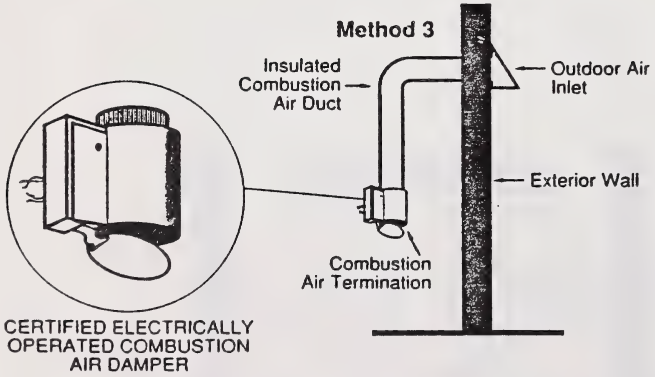

Heating Coil
Filter
Ventilation Air to Living Areas of Home (dotted section shown for guidance only)
Insulated Ven Air Duct
Insulated Combustion Air Duct
Boiler
Exterior Wall
For Combustion Air Termination Options See pages No. 4 and 5


Insulated Ventilation Air Duct (dotted section shown for guidance only)
Return Air Duct
Supply Air Duct
Insulated Combustion Air Duct
Furnace
Exterior Wall
For Combustion Air Termination Options See pages No. 4 and 5

COMBUSTION AIR TERMINATION OPTIONS FOR ALL APPLIANCES

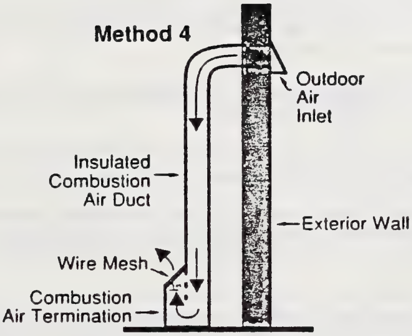


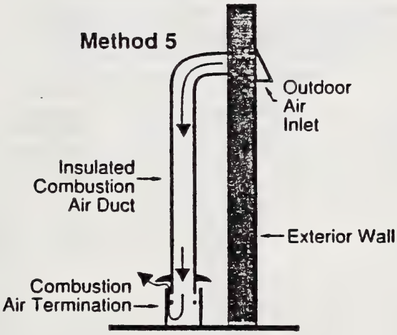



Method 3
Insulated Combustion Air Duct
Outdoor Air Inlet
Exterior Wall
Combustion Air Termination
CERTIFIED ELECTRICALLY OPERATED COMBUSTION AIR DAMPER

NOTE Other methods may be used provided they are accepted by the local building and gas inspection branches prior to installation.

Following combustion air terminations may be used for solid fuel or oil fired appliances. They may also be used for gas fired appliances if the termination point meets the B149 Code requirements of within 300 mm above and within 600 mm horizontally from the burner level of the appliance having the largest input.





NOTE 15 kW = 50,000 Btu/h (approx.)

5.3 Air Supply Openings and Ducts

5.3.1 Except as specified in 5.3.3, a duct shall be used to provide the outside *air supply* required by 5.2.1 and 5.2.3. The duct shall

(a) be of either metal, or a material meeting the Class I requirements of CAN4—S110 Standard for Air Ducts;

(b) be of at least the same cross-sectional area as the free area of the *air supply* inlet opening to which it connects; and

(c) terminate within 1 ft (300 mm) above, and within 2 ft (600 mm) horizontally from, the *burner* level of the *appliance* having the largest input.

5.3.2 A square or rectangular shaped duct shall only be used when the required free area of the *air supply* opening is 9 square inches (5800 mm^2) or larger, and when used its smaller dimension shall not be less than 3 inches (75 mm).

5.3.3 An opening may be used in lieu of a duct to provide the outside *air supply* to an *appliance(s)* as required by 5.2.1 and 5.2.3, and unless otherwise permitted by the *authority having jurisdiction*, the opening shall be located

TABLE 5.2.2A
Combustion/Dilution Air Requirements for Appliances Having Draft Control Devices When the Combined Input is up to and including 400 000 Btuh (120 kW) and the Structure Complies with 5.2.1 (a) or (b)

Total Input of Appliances* Thousands of Btuh (kW)	Required Free Area of Air Supply Opening or Duct Square Inches (mm^2)	Acceptable Approximate Round Duct Equivalent** Diameter in Inches (mm)
25 (8)	7 (4 500)	3 (75)
50 (15)	7 (4 500)	3 (75)
75 (23)	11 (7 000)	4 (100)
100 (30)	14 (9 000)	4 (100)
125 (37)	18 (12 000)	5 (125)
150 (45)	22 (14 000)	5 (125)
175 (53)	25 (16 000)	6 (150)
200 (60)	29 (19 000)	6 (150)
225 (68)	32 (21 000)	6 (150)
250 (75)	36 (23 000)	7 (175)
275 (83)	40 (26 000)	7 (175)
300 (90)	43 (28 000)	7 (175)
325 (98)	47 (30 000)	8 (200)
350 (105)	50 (32 000)	8 (200)
375 (113)	54 (35 000)	8 (200)
400 (120)	58 (37 000)	9 (225)

* For total inputs falling between listed figures, use next largest listed input.

** These figures are based on a maximum equivalent duct length of 20 ft (6 m). For equivalent duct lengths in excess of 20 ft (6 m) up to and including a maximum of 50 ft (15 m), increase round duct diameter by one size.

THE CITY OF EDMONTON REQUIREMENTS

Edmonton

November 23, 1987

TO: ALL SHEET METAL CONTRACTORS,
MECHANICAL CONTRACTORS AND HOME BUILDERS

RE: COMBUSTION AIR AND VENTILATION AIR FOR ALL NEW DWELLING UNITS

The following is for your information and action.

All new heating and ventilation systems installed after December 31, 1987, shall be installed according to the enclosed Standata 85-DI-017R covering combustion air and ventilation air for all dwelling units. Exception to the Standata for combustion air would be other methods such as the A.C.A.P.A.C.

The combustion air duct and components shall be insulated and be of either metal, or a material meeting the Class I requirements of CAN4-S110, "Standards for Air Ducts".

The mechanical ventilation system for make-up air and exhaust shall be a balanced system designed to meet the requirements of (1/2 air change per hour).

Articles 9.33.3.1. and 9.33.3.3. of the Alberta Building Code 1985 state, as follows:

9.33.3.1. - Dwelling units shall have a mechanical ventilation system capable of providing at least one half an air change per hour during the heating season, based on the interior finished volume of the dwelling unit. This system shall be controlled either manually by a switch or automatically. (See Appendix A.)

A-9.33.3.1. - Mechanical Ventilation. The tendency toward achieving higher levels of airtightness in housing and other concerns over energy conservation indicate that natural ventilation is not sufficient to ensure acceptable air quality during the winter heating season. The mechanical system required by this Article is, therefore, independent of natural sources, including windows and air infiltration.

This Article does not require that a centralized ventilation system be provided with duct work leading to all parts of the dwelling unit. The requirement may be satisfied by means of exhaust fans located in kitchen or bathroom areas where a fresh air inlet is provided at a location remote from the exhaust outlet. A ventilation system operating in conjunction with a central heating or cooling system comes under the jurisdiction of Part 6.

9.33.3.3. - Mechanical ventilation systems for dwelling units shall include provision for introduction of fresh make-up air from the exterior.

Further to the ventilation requirements, all Heating & Ventilation Permits will require that following information entered on the Permit Application. Failure to do so will delay Permit acceptance and occupancy requests.

1. Volume of the dwelling (cubic feet).

2. C.F.M. required.

3. Type of System (for example):
    1. Self-contained intake and exhaust
    2. Self-contained with H.R.V. unit
    3. Integrated ventilation/forced air
    4. Integrated with H.R.V.
    5. Fan/heating coil

4. Under Type of Equipment, Enter (for example):

Manufacturer	Model
Broan	(No. of C.F.M.)

Should you require further information, please feel free to contact me at 428-5866.

Yours truly,

K. W. WILLISKO, Director
Heating & Ventilation Inspection Section
Building Inspection Branch
Planning & Building Department

KWW/mdm

Enc.

CSA Preliminary Standard
F326.1-M1989
Residential Mechanical Ventilation Requirements

1. Scope

1.1

This Standard defines the requirements for mechanical ventilation systems whose purpose is to provide the minimum controlled rates of ventilation air to the habitable spaces of those single-family dwellings that fall within the Scope of Part 9 of the National Building Code and that are self-contained with respect to heating, ventilation, and air conditioning.

1.2

The amounts of ventilation and exhaust air specified in this Standard are intended to deal with contaminants at the rate of generation normally encountered in residential dwellings. Acceptable indoor air quality also requires that the rate of contaminant emission be controlled. Where abnormal contaminants or unusually high rates of emissions occur, or where unusually low concentration limits are specified, measures going beyond the provisions of this Standard may be required. Where outdoor air is used for summer cooling, the rates of ventilation air supply required will often be much higher than those specified in this Standard.

1.3

In establishing the requirements for mechanical ventilation systems, it is necessary to consider the house as a "system" that has ventilation subsystems which move air into and out of a building while taking into account the leakage characteristics of the envelope. Factors such as climatic conditions, the leakage characteristics of a dwelling unit envelope, and the operation of combustion and ventilation equipment affect indoor/outdoor pressure differences; this in turn influences the performance of combustion and ventilation equipment, as well as the long-term integrity of the structure.

1.4

This Standard takes no account of the ventilating effects of uncontrolled air leakage, of natural ventilation through open windows, or of other such openings operated by the occupants. It does account for the effect of uncontrolled leakage through the building envelope on the relative difference between indoor and outdoor air pressure. The ventilation provided by these means will augment the ventilation provided by the mechanical system.

1.5

The ventilation air requirements of this Standard are not intended to provide for the combustion and dilution air needs of vented fuel-burning appliances. These are specified in the Standards referred to in Clause 4.2. This Standard does incorporate provisions intended to limit the depressurization of the house induced by the operation of the ventilation system and exhaust appliances in order to minimize adverse effects on the venting of fuel-burning appliances and fireplaces.

1.6

This Standard does not consider the air supply required for combustion in fireplaces nor the supply of makeup air required to account for that exhausted through the fireplace flue. Any such requirements are above and beyond those included in this Standard.

2. Definitions

2.1

The following definitions apply in this Standard:

Basement—a storey or storeys of a building located below the first storey. First storey refers to the uppermost storey having its floor level not more than 2 m above grade.

Bathroom—any room containing a toilet, urinal, bidet, bathtub, or shower.

Base flow-rate condition—the operating condition of the ventilation system when providing the base flow rate of ventilation air as required by Clause 5.1.1(b).

Base flow rate of ventilation air—the minimum average rate of ventilation air achieved per day.

Building envelope—the surfaces, formed by all components of the building, that enclose the conditioned volume.

Conditioned volume—the total interior volume of all storeys, including the basement, but excluding any attached or built-in garage or crawl space.

Dwelling unit—a suite operated as a housekeeping unit, used or intended to be used as a domicile by one or more persons, and containing cooking, eating, living, sleeping, and sanitary facilities.

Exhaust air—air removed from a space such that it will not be reused.

Habitable room—a space or room designed for human occupancy, such as a bedroom, living room, dining room, kitchen, family room, recreation room, or den.

Heat recovery ventilator—a factory-assembled unit that incorporates a means to circulate air for ventilation and the provision to transfer heat between two isolated air streams.

Makeup air—outdoor air supplied to replace exhaust air.

Occupied zone—the region within an occupied space between 75 and 1800 mm above the floor and more than 600 mm from the walls or fixed air-conditioning equipment.

Outdoor air—air from the external atmosphere taken into the dwelling unit (without significantly increasing the interior contaminant level) that has not previously been circulated through the ventilation system.

Outdoor winter design temperature—the January 2-1/2% value as given in Table 5 of CSA Standard CAN/CSA-F280, *Determining the Required Capacity of Residential Space Heating and Cooling Appliances.*

Recirculated air—air removed from the conditioned space and intended for reuse as supply air.

Reference exhaust flow rate—the sum of the exhaust components as defined in Clause 6.3.

Return air—air removed from a space to be recirculated or exhausted.

Supply air—air delivered to the conditioned space and used for ventilation, heating, cooling, humidification, or dehumidification.

Utility room—a room containing laundry or maintenance equipment and materials, or used as a workshop.

Ventilation—the process of supplying and/or removing air by natural or mechanical means to and from any space.

Ventilation air—that portion of supply air which is outdoor air.

Ventilation system—all of the components installed for the purpose of providing the controlled ventilation air called for in this Standard.

3. Reference Publications

3.1

This Standard refers to the following publications and where such reference is made it shall be to the edition listed below:

CSA Standards
B139-1976,
Installation Code for Oil Burning Appliances;
CAN/CSA-B365-M87,
Installation Code for Solid-Fuel-Burning Appliances and Equipment;
CAN/CSA-F280-M86,
Determining the Required Capacity of Residential Space Heating and Cooling Appliances.
CGA* Standards
CAN/CGA-B149.1-M86,
Natural Gas Installation Code;
CAN/CGA-B149.2-M86,
Propane Installation Code.
ASHRAE† Standard
62-1981,
Ventilation for Acceptable Indoor Air Quality.
National Building Code of Canada, 1985

**Canadian Gas Association.*
†*American Society of Heating, Refrigerating and Air-Conditioning Engineers.*

4. General Requirements

4.1

Mechanical ventilation systems and equipment shall be installed in conformance with the appropriate provincial requirements or, in the absence of such requirements, with the appropriate sections of Part 6, "Heating, Ventilating, and Air Conditioning" and Part 9, "Housing and Small Buildings" of the current edition of the *National Building Code of Canada.*

4.2

Air shall be provided for combustion and venting of fuel-fired appliances in accordance with the provisions of the governing provincial codes. In the absence of specific provisions, the requirements of the following shall apply as appropriate:

(a) CGA Standards CAN/CGA-B149.1 and CAN/CGA-B149.2;
(b) CSA Standard B139;
(c) CSA Standard CAN/CSA-B365.

5. Ventilation Air Requirements

5.1 Base Flow Rate for Dwelling Units

5.1.1

The ventilation system shall be designed so that it can

(a) operate on a continuous basis, except as permitted by Clause 5.1.2; and
(b) provide a base flow rate of ventilation air to the dwelling unit that is the greater of
(i) the sum of the individual room requirements as defined in Column 1 of Table 1; or
(ii) 0.3 air changes per hour (ac/h), based on the conditioned volume of the dwelling unit.

5.1.2

Where the operation of the system requires periods when no ventilation air is provided (eg, during defrosting of some heat recovery ventilators), the system shall be designed so that the total time of no ventilation air supply does not exceed 1 h within any 2 h period and so that the average flow rate of ventilation air in any 24 h period is not less than the base flow rate as required by Clause 5.1.1.

5.1.3

Where there is a reduction in ventilation flow rate as a result of an increase in resistance to air flow during operation (eg, frosting of heat exchangers in exhaust heat recovery devices), the base flow rate shall be

Table 1
Minimum Ventilation Air Requirements

	Column 1	Column 2**	Column 3**
Space classification	Base flow rate, L/s*	Intermittent exhaust, L/s*	Continuous exhaust, L/s*
Category A			
Double/Master bedroom	10	—	—
Basement†	10	—	—
Single bedrooms	5	—	—
Living room‡	5	—	—
Dining room‡	5	—	—
Family room	5	—	—
Recreation room	5	—	—
Other§	5	—	—
Category B			
Kitchen‡	5	50	30
Bathroom	5	25	15
Laundry	5	—	—
Utility room	5	—	—

**Based on air at a density of 1.204 kg/m^3.*
†*Each area in a basement that is separated by a wall and doorway shall have a minimum ventilation requirement of 5 L/s. This does not include furnace rooms, storage rooms, and closets.*
‡*Ventilation requirements for any combined living room, dining room, and kitchen shall be determined as if they were individual rooms.*
§*Other habitable rooms not listed shall have a minimum ventilation requirement of 5 L/s. This does not include spaces intended solely for access, egress, or storage, such as vestibules, halls, landings, and storage rooms.*
***Either intermittent or continuous exhaust is required (see Clause 5.3).*

based on the minimum average flow rate in any 24 h period.

Note: *This does not include reduction in flow resulting from lack of maintenance by the occupants (eg, cleaning of air filters).*

5.2 Base Flow Rate for Rooms

5.2.1 General

Provided the requirements of Clause 5.1.1 are satisfied, the system shall be designed to supply a daily average base flow rate of ventilation air to all Category A and B rooms at rates not less than those called for in Column 1 of Table 1, except as provided in Clauses 5.2.3 and 5.2.4.

5.2.2 Category A Rooms

Category A rooms are those which may be occupied for extended periods and are not major sources of moisture. Where the design of the system requires that room air be returned to a recirculating fan and/or be exhausted to the outdoors either by a mechanical exhaust fan or through vents, there shall be an adequate path at all times for the supply air to move from each Category A room to the return or exhaust air opening(s) intended to serve it.

5.2.3 Category B Rooms

Category B rooms are those which are not typically occupied for extended periods and/or are sources of moisture and/or odour. Provided the requirements of Clause 5.1.1 are satisfied, ventilation air to Category B rooms called for in Column 1 of Table 1 can be provided indirectly from other rooms in the dwelling unit through continuous exhaust from Category B rooms at rates not less than 5 L/s. There shall be an air path at all times for air to move into such a Category B room from the room(s) having an air supply intended to serve it. Air removed from kitchens and bathrooms shall be exhausted directly to the outdoors.

5.2.4 Recirculation Systems

Provided the requirements of Clause 5.1.1 are satisfied, where the ventilation air is distributed through a central recirculation system at a circulation rate of not less than 1 ac/h based on the conditioned volume of the dwelling unit,

(a) the requirement of Clause 5.2.1 for Category A rooms shall be deemed to be satisfied in any room in which the total air continuously supplied or removed by the recirculation system is not less than 20 L/s; and

(b) the requirement of Clause 5.2.1 for Category B rooms shall be deemed to be satisfied if the total air supplied or removed is not less than 5 L/s.

5.3 Exhaust from Kitchens and Bathrooms

There shall be a capability to exhaust air from kitchens and bathrooms either on an intermittent basis at rates not less than those in Column 2 of Table 1 or on a continuous basis at rates not less than those in Column 3 of Table 1. All such exhaust air extracted from bathrooms and kitchens shall be exhausted directly to the outside and shall not be recirculated. This does not preclude the use of exhaust air heat recovery devices, provided that leakage from the exhaust to the supply air stream does not constitute more than 5% of the ventilation air stream.

5.4 Room Air Distribution

Ventilation systems shall be designed so that ventilation air is circulated throughout the occupied zone. Short circuiting of air movement from supply to return air grilles shall be avoided.

5.5 Supply Air Temperature—Thermal Comfort

The system shall be designed and installed so that the temperature of ventilation air and its manner of introduction into each room are such as to avoid discomfort in the occupied zone.

5.6 Minimum Supply Air Temperature—Fuel-Fired Furnaces

Where ventilation air is introduced into the return air plenum of a fuel-fired furnace, it shall be tempered and/or mixed with return air so that the temperature of the circulating air in contact with the furnace's primary heat exchanger is not less than 12°C. Design shall be based on the 2-1/2% outdoor winter design temperature and a return air temperature of 20°C.

5.7 Minimum Surface Temperature of Ducts

To control condensation on the exterior surfaces of air distribution ducts, the ventilation air shall be tempered and/or mixed with return air and/or the ducts shall be insulated so that when the outdoor temperature is at the 2-1/2% outdoor winter design temperature, the exterior surface temperature of the ducts shall be not less than 14°C.

6. Dwelling Unit Pressure Design Requirements

6.1 Pressure Increase Limits

The ventilation system shall be designed so that, when operated at the base flow-rate condition,

(a) the sum of all flows through intake components (supply fans and intake vents) does not exceed the sum of all flows through exhaust components (exhaust fans and exhaust vents) by more than 0.12 L/s/m² of the interior surface of the building envelope, and

(b) the pressure increase in the dwelling unit relative to the outside does not exceed 10 Pa.

6.2 Pressure Decrease Limits—Base Flow-Rate Condition

Operation of the ventilation system at the base flow-rate condition shall not contribute to decreasing the pressure in the dwelling unit relative to the outside by more than 10 Pa, except that the pressure decrease shall not exceed 5 Pa for dwelling units incorporating Category I appliances as defined in Clause 6.3.2.

6.3 Pressure Decrease Limits—Reference Exhaust Flow-Rate Condition

6.3.1 General

The reference exhaust flow rate used in this Clause shall be the sum of the following components:

(a) the net exhaust flow rate of the ventilation system under the base flow-rate condition; and

(b) the net exhaust flow rate of the clothes dryer, or if one is not installed then a default value of 75 L/s; and

(c) the net exhaust of the two mechanical exhaust devices that provide the greatest net exhaust over and above any devices contributing to the net exhaust of (a) and (b), whether or not they are a part of the ventilation system.

6.3.2 Category I Fuel-Burning Appliances

For the purposes of this Clause, Category I fuel-burning appliances are those that take combustion and dilution air from the dwelling unit, are approved for use and installed with draft hoods, draft regulators, or other sources of dilution air, and depend upon natural draft to vent products of combustion to outdoors. For dwelling units incorporating Category I appliances, operation of the ventilation system under reference exhaust flow-rate conditions shall not contribute to decreasing the pressure in the dwelling unit relative to the outside by more than 5 Pa.

6.3.3 Category II Fuel-Burning Appliances

For the purposes of this Clause, Category II fuel-burning appliances are those that take combustion air from the dwelling unit, are approved for use and installed with sealed flues that have no openings through which combustion gases can enter the dwelling unit, and have gas-tight and corrosion-resistant flue surfaces.

For houses incorporating Category II appliances, operation of the ventilation system under reference exhaust flow-rate conditions shall not contribute to decreasing the pressure in the dwelling unit relative to the outside by more than either 10 Pa or the value for which the appliance has been certified by an accredited certification agency.

6.3.4 Category III Fuel-Burning Appliances

For the purposes of this Clause, Category III fuel-burning appliances are those that take combustion air directly from outside through a connection sealed from the atmosphere in the dwelling unit, are approved for use and installed with sealed flues that have no openings through which combustion gases can enter the dwelling unit, and have gas-tight and corrosion-resistant flue surfaces.

For houses incorporating Category III appliances, operation of the ventilation system under reference exhaust flow-rate conditions shall not contribute to decreasing the pressure in the dwelling unit relative to the outside by more than either 20 Pa or the value for which the appliance has been certified by an accredited certification agency.

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